U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-260 889

Proceedings Urban Stormwater Management Seminars Held at Atlanta, GA on Nov 4-6, 1975, & Denver, CO on Dec 2-4, 1975

Environmental Protection Agency, Wash, D.C. Div. of Water Plng.

Jan 76

WATER QUALITY MANAGEMENT GUIDANCE
WPD 03-76-04
343097

PB 260 889

proceedings

URBAN STORMWATER MANAGEMENT SEMINARS

ATLANTA, GEORGIA NOV. 4-6 1975
DENVER, COLORADO DEC. 2-4 1975

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

BIBLIOGRAPHIC DATA SHEET

1. Report No.

2.

3. Recipient's Accession No.

4. Title and Subtitle
Proceedings Urban Stormwater Management Seminars
Atlanta, Georgia Nov. 4-6 1975
Denver, Colorado Dec. 2-4 1975

5. Report Date

6.

7. Author(s)
Dennis N. Athyde

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

Water Planning Division
Planning Assistance and Policy Branch

10. Project/Task/Work Unit No.

11. Contract/~~Grant~~ No.
EPA 68-01-3565

12. Sponsoring Organization Name and Address

Same as above

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstracts

This project was designed to provide initial guidance for the developement of work plans pursuant to Section 208 of PL 92-500. Three areas are discussed. The first is problem assessment for pollution from urban stormwater runoff. Second area covered discusses means to control pollution, and the third area deals with the legal, institutional, and financial aspects of controlling urban stormwater runoff for pollution abatement. The report of the two seminars includes transcribed tapes of question and answer periods which were held after each of the three areas were discussed.

Included is a bibliography on institutional arrangements.

17. Key Words and Document Analysis. 17a. Descriptors

Pollution abatement
Legal
Institutional
Financial
Problem Assessment

17b. Identifiers/Open-Ended Terms

Urban Stormwater Runoff
Best Management Practices (BMP)

17c. COSATI Field/Group

18. Availability Statement

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages 513

22. Price $ 12.7

PROCEEDINGS

URBAN STORMWATER MANAGEMENT SEMINARS

Atlanta, Georgia
November 4-6, 1975

and

Denver, Colorado
December 2-4, 1975

Contract No. 68-01-3565

Project Officer

Dennis N. Athayde
Planning Assistance and Policy Branch
Water Planning Division
Office of Water and Hazardous Materials
Washington, D.C. 20460

January 1976

EPA REVIEW NOTICE

This report has been reviewed by the Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

TABLE OF CONTENTS

Preface v
Introduction to Program vii
Welcoming Remarks
  Atlanta viii
  Denver ix

I. Characterization of the Urban Stormwater Problem I-1

  Best Management Practices, Dennis Athayde I-2

  Considerations in Characterization of Urban Runoff, Francis J. Condon I-7

  Land Use and Urban Development Affecting Stormwater Pollution and Water Quality, Herbert G. Poertner I-38

  Instream Impacts of Urban Runoff, Eugene D. Driscoll I-54

  Impact of Combined Sewer Overflows and Storm Sewer Discharges on Water Quality, John A. Lager I-83

  NPS Impact and Urban Holding Capacity: Major Issues, G. Kenneth Young I-98

  Runoff and Quality, Eugene D. Driscoll I-122

  Applications of Stormwater Management Models, John A. Lager I-157

II. Approaches to the Urban Stormwater Problem II-1

  Land Management Techniques for Stormwater Control in Developed Urban Areas, Kathleen C. Adgate II-2

  Land Management Techniques for Developing Areas, L. Duane Bartee (Denver) II-38

  SCS Practices as Related to Sediment and Erosion Control, August Dornbusch (Atlanta) II-56

  Cost Effective Approach for Combined and Storm Sewer Cleanup, William C. Pisano II-62

  Collection System Control, John A. Lager II-83

  Treatability Determinations for Prototype Swirl Combined Sewer Overflow Regulator/Solids-Separator, Richard I. Field II-99

Urban Stormwater Detention and Flow Attenuation for Water Pollution Control, Herbert G. Poertner II-118

III. Institutional/Legal Issues of Urban Stormwater Management III-1

Urban Stormwater Management - Problems and Solutions, Herbert G. Poertner III-2

The Intergovernmental Tangle Facing Stormwater Control, Andrew Waldo III-15

State/Local Interaction in Stormwater Management, Eugene T. Jensen III-45

Legal Aspects of Urban Stormwater Management, W. Joseph Shoemaker (Denver) III-57

Legal Aspects of Urban Stormwater Management and Related Pollution Abatement Problems, Frank E. Maloney (Atlanta) III-67

Financing Stormwater Control Projects, Jay Fountain and Dwight Cochran (Atlanta) III-107

Financing Stormwater Projects, W. Joseph Shoemaker (Denver) III-113

Planning to Narrow the Implementation Gap, Richard Page and Penelope Wilson (Denver) III-122

Implementation of Urban Stormwater Runoff Plans, George C. Berteau (Atlanta) III-132

Urban Stormwater Management Information Form: Summary of Responses, Warren W. Gast III-141

General Comments, Jerry G. Cleveland III-145

Appendix A. Seminar Participants, Atlanta and Denver

Appendix B. Seminar Agendas, Atlanta and Denver

Preface

The Federal Water Pollution Control Act Amendments of 1972, Section 208, call for the establishment of a regulatory program to include urban stormwater management. The 1974 Needs Survey arrived at a rough national cost estimate of $235 billion for treatment of stormwater runoff, in addition to the $31 billion for prevention of combined sewer violations. Thus, while the elimination of discharges into navigable waters by 1985 has been established as a national goal, and while the contribution of storm-generated pollution has been recognized as a major deterrent to the attainment of this goal, complete treatment of stormwater pollution is economically unfeasible. Therefore, approaches other than complete treatment of stormwater must be developed, approaches which attain acceptable reduction of pollutants at an acceptable cost.

The traditional philosophy for control of urban stormwater has been corrective in nature; that is, an after-the-fact attempt to manage the problem. This has often necessitated development of large downstream flood prevention facilities to accommodate the volumes and peak rates resulting from upstream urbanization, and extensive collection and treatment systems to handle pollutant loadings. Despite these costly corrective facilities, pollution of receiving waters, flooding and property damage still occur, for the variability of storm events assures that, no matter what size storm a facility is designed for, it will be inadequate for some storm events.

The alternative to this corrective philosophy is the preventative concept of source control; that is, abating the problem as it occurs, and before it attains a magnitude that is difficult to control at a reasonable cost. Applied on a watershed basis, preventative techniques for stormwater control can cost-effectively reduce the aggregate amount of pollution and flooding that might otherwise occur at downstream facilities.

Application of preventative techniques on a watershed basis is often difficult to accomplish, however. Responsibility for urban stormwater management is often distributed over numerous Federal, State, and local government agencies and may be conflicting and ill-defined. Consideration is often not given to the interjurisdictional nature of urban runoff. Legal questions arise as to the reasonableness of regulations for stormwater control, as to operation and maintenance responsibilities, and as to who should pay for urban stormwater control systems.

The 208 planning process provides a mechanism through which interjurisdictional management of urban stormwater can be addressed, and through which the agencies with expertise (i.e., EPA, USGS, HUD, SCS) can interface their knowledge and research for a more holistic approach to urban stormwater problems.

With these considerations in mind, the Water Planning Division of the U. S. Environmental Protection Agency conducted two Urban Stormwater Management Seminars in November-December of 1975. The purpose of these seminars was to disseminate information to 208 agencies, their consultants, and State water quality personnel on some of the alternative approaches to stormwater control and to provide a forum, both formal and informal, for interagency communication on problems and approaches. The proceedings from these seminars include the formal presentations as well as many of the questions and responses from the informal sessions. The presentations have not been edited, due to the Water Planning Division's desire to provide this information in a timely fashion for 208 planning purposes.

These seminars were conducted under a contract to Herbert Poertner, Research and Engineering Consultant, who provided for speaker participation and for conference arrangements. Regions IV and VIII hosted the seminars, and recognition and thanks are extended to Scott Berdine and Paul Ferraro and their staffs for their many contributions.

These proceedings are intended to give the reader a general overview of the urban stormwater problem. The first section is directed toward: a characterization of the problem, discussion on the viewpoint of the Division toward stormwater management, data collection and analysis, and modeling. Section Two covers some alternative techniques of stormwater management. Issues concerning implementation are addressed in the last section and include financial, legal, and institutional problems. This document does not purport to contain all answers to the reader's specific stormwater problems, but will, hopefully, provide guidance through the formal presentations, questions, and responses, and bibliographies that follow.

INTRODUCTION TO PROGRAM

by James Meek
Water planning Division
U.S. Environmental Protection Agency
Washington, D.C.

This is the first in a series of technical sessions that we are planning. There will be another stormwater seminar in Denver, December 2-4, which is a replay of this one. We are trying to offer these courses in different parts of the country so that travel isn't prohibitive. A water quality monitoring course will be given in Cincinnati, December 8-12. We haven't anything else scheduled, but we're going to have either 1-day or 2-day sessions on other non-point source problems, such as mining, agriculture, silvaculture, et cetera. These will be handled by R & D. They will be workshops, organized to provide an exchange of information.

This brings us to what we want you to get out of this seminar. Basically, it's three things: first of all, we want a two-way exchange of information. In other words, we are going to provide the state-of-the-art and we want you to give us feedback of what your problems are and what you want from us. We also want an interchange among yourselves. Finally, we want your reactions. This is the first of the series and we want to know what kind of help really helps and which future courses can really help you do your job.

We realize that the two-year study and planning period is a very short time. This makes it practically impossible to document successes and failures and get such information distributed before it is too late. We are relying heavily on these kinds of sessions and we want to tailor them to your needs. We will be very interested in your appraisal of this seminar and what your reactions are. Please let us have your evaluations before you leave the seminar.

WELCOMING REMARKS

by John A. Little
Deputy Regional Administrator, Region IV
U.S. Environmental Protection Agency
Atlanta, Georgia

We had a briefing yesterday with the Office of Management and Budget in Washington. Each year they pick one EPA region with which to discuss the upcoming budget. I know that a lot of you are associated with Section 208 planning. One of the things we talked about is non-point-source pollution. I know that OMB has impressions regarding the fact that the 208 planning areas are often SMSA's and, as such, are pretty closely tied to the metropolitan areas. So, they reason, when you develop your plan, isn't all this non-point-source runoff going to pollute the streams anyway? Their concept of the non-point source problem is agriculture, primarily. I tried to tell them that urban stormwater is probably a much bigger problem than agricultural runoff in any one of these areas.

We don't have too many stormwater problems in the Southeast, compared to many areas of the country. However, we have a nice problem in Atlanta. We have a new plant on the Chattahoochee River which gets overloaded whenever it rains. We're running into this kind of problem in a few other areas.

One of my former staff from Athens, Georgia has been working on stormwater problems related to environmental impact statements. There is no area that EPA and its predecessors have spent more money on, through demonstration projects, than this total stormwater management problem. I think we're looking for some answers and applications to conquer this problem.

We are very glad to have you here in Atlanta. Have a good meeting!

WELCOMING REMARKS

by Charles Murray
Director, Division of Water Programs
U.S. Environmental Protection Agency
Region VIII, Denver, Colorado

I am on the program today to give you a welcome from my boss, Jack Green, Regional Administrator of Region VIII, who is in Washington, D.C. today. I think it is an interesting coincidence that today is the Environmental Protection Agency's fifth birthday. Five years ago today we were created by executive order. Needless to say, it has been an interesting five years. And, frankly, I think that the system has been successful; and, by the "system", I'm referring to many of the professionals in this room, including representatives of the Environmental Protection Agency, State governments, local governments, and industry, as well as private citizens and elected officials.

I think it has been a team effort over the past five years to try to respond to some very significant national legislation addressed to protecting our environment. I think real progress has been made in a very substantive beginning in the past five years. Jack wanted me to touch on some of the things that we see that are so exciting about the 208 program. We feel that there are great opportunities, particularly in this Region, to get out in front and implement our "prevention" strategy which, in our Region, is every bit as important as "abatement" strategy.

The 208 program is a unique tool to us to do this sort of prevention planning and get out ahead of the problems to avoid repeating mistakes of the past. When we look at this 208 program, there are three or four things that we try to emphasize. Today I have the opportunity to talk to a group of people who are dealing day-to-day with the 208 program. You are the ones who have to make it work. I think I ought to share with you where we're coming from and things that we see that are so important in this process.

The first thing is that we are trying to develop a greater "environmental awareness" in the planning process--not just for the water dimension, but to really look at environmental planning and build a continuing planning process that is financially self-sufficient where it really conserves the environment in the decision-making process. We're trying to strengthen water quality management, when you look at the planning part of it, as another tool for management--a very important tool for management in making decisions that really consider environmental impact.

We're trying to develop an environmental sensitivity throughout this planning process so that, whether you wind up with an environmental assessment or the full-blown environmental impact statement, your planning process is going to be able to withstand close scrutiny by people who are interested in protecting the environment.

We're talking very seriously about implementation--and "early-on" implementation, taking actions now and not waiting for the end of the planning process. I see no real reason for that kind of delay. There are ordinances and regulations that can be passed today by local government that could really protect the environment--particularly in relation to activities in managing the land that impact on water quality. So you're going to hear, when dealing with EPA Region VIII, these messages and themes, over and over again, because these, we think, are completely integral to a successful 208 planning process.

Turning to the subject matter today, which is an "Urban Stormwater Management Seminar", we're turning to a area that I've been interested in for a long, long time. It is with a great deal of interest that I approach the subject matter that you're going to be addressing for the next three days.

Quite frankly, in the past, the planning part was the easy part. The implementing part was the difficult part, and that's still true of most anything we do. But I think it is particularly true when we deal with storm drainage because you come face-to-face with money problems, and that is the "key" problem in implementing storm drainage plans, in my judgement. At least, that has been my experience.

As a result of five public hearings that we held across the country dealing with changes in P.L. 92-500, one of the changes that EPA recommended to Congress was that we eliminate storm sewers as eligible for construction grant funds. When you look at the national needs for treatment and major interceptors, you can see the restraints imposed upon the system and why this kind of recommendation must be seriously considered. I think that this demonstrates that, when you're dealing with the stormwater runoff element of the urban environment, funding is going to be critical. So, I think that it behooves you to look at non-structural, "preventive"measures and controlling new activities. These are things you can do today, and quite simply. So, I think that, although you are going to have to look at this in the systems context, you are going to have to put a great deal of emphasis on the non-structural, preventive aspects for the urban stormwater management element in the 208 program.

I've taken longer then I was supposed to, but Jack did want me to share with you some of his thoughts. He was sorry he could not be here. We think that this seminar is going to be extremely useful to you in evaluating your urban storm drainage problems. We are happy to be a part of it and provide you some assistance in the technical area that you are grappling with.

I am sure that this seminar is going to serve a useful purpose to you.

I think it goes without saying that it is going to require a very cooperative team effort from all of us if we are going to be able to isolate and examine the urban stormwater problem, and then integrate that element into our overall water quality management program. I wish you a lot of luck in the next three days and a lot of luck in going back home and applying what you learned to the 208 process in your area. Thinks very much for coming. It has been a real pleasure to talk to you.

I. Characterization of the Urban Stormwater Problem

Best Management Practices (BMP)

Dennis Athayde

Water Planning Division

This morning I would like to tell you about the latest thinking, within the Water Planning Division, on the management of urban runoff. I would like to tell you what the policy is going to be, but I can't. Because the issue of whether or not urban runoff is to be treated, managed, or brought under the National Pollution Discharge Elimination System has not been fully resolved by the Agency at this time.

As your know, Section 208 addresses nonpoint sources, of which urban runoff is one. Or at least has been considered as one in the past.

In the court decision of the National Resources Defense Council versus Russell E. Train (DDC 1629-73), known as the Flannery decision, or the Feedlots Case, the issue that was resolved, after an appeal, was that the Administrator does not have the latitude to exempt entire classes of point sources from the NPDES permit requirements. The order from the decision is that by November 10, 1975 the Agency will publish proposed regulations extending the NPDES system to include all point sources, including separate storm sewer categories, and final regulations are to be published by March 10, 1976. The final judgement went on to say that the Agency is to determine the approach and strategy to be followed in regulating previously excluded point sources ... including determination of appropriate technologies or management procedures to reduce pollution from these categories.

Best Management Practices (BMP)

What is BMP? What is a best management practice? The Guidelines for Areawide Waste Treatment Management Planning,August 1975, defines BMP as "... a practice or combination of practices that is determined by a State after examination of alternative practices to be practicable and most effective in preventing or reducing the amount of pollution generated by a nonpoint source to a level compatible with water quality goals."

BMP is a mechanism that emphasizes the management of sources of pollutants, and the preventive approach. A BMP is comprised of several management techniques and its composition is dependent on the area it serves. It is these practices or techniques that we will talk about here.

The Urban Stormwater Problem

The stormwater runoff problem is a direct result of urban growth and development. Roughly eighty percent of the population of the U.S.

is now urbanized, with the process of urbanization proceeding at an estimated rate of about 1,500 square miles per year. While the problem is growing, the scarcity of information available on the impact of stormwater flows on receiving water quality poses a serious problem to the development and administration of effective local management programs.

Pollution from urban runoff occurs when precipitation flushes the urban environment and carries pollutants to receiving waters. Potential pollution - from roof tops, streets, parking lots, shopping centers, commercial buildings, industrial complexes, automobiles, etc. - forms across the surface of an urban area, and tends to increase in depth with an increase in time between precipitation events.

As the surface is flushed, the polluted water flows overland toward the collection systems. The initial collection systems are the land surface and roof tops, which slope toward the secondary collection systems of roadways, streets, gutters and drains, where surface water concentrates as it flows into the sewerage systems. These sewerage systems are of two general types, separate and/or combined. Separate storm sewers generally convey only storm or snowmelt runoff, whereas combined sewers carry both storm and snowmelt runoff and untreated municipal wastewater. Separate storm sewers generally discharge directly into the receiving waters at many locations. Combined sewers usually have flowsplitting devices which bypass a high percentage of untreated combined sewage directly to the receiving waters, and the remaining smaller fraction receives some treatment before being discharged.

Considering the route that runoff takes, it is not surprising that polluted runoff contains substantial amounts of organic material, inorganic solids, nutrients, heavy metals and microorganisms, which can have a significant impact on receiving water quality.

The total annual pollutant load in stormwater, during storm runoff periods, can be greater than the annual pollutant load discharged from municipal treatment plants during dry weather. This could preclude meeting water quality standards regardless of the degrees or types of treatment afforded dry weather wastewater flows.

Unregulated runoff leads to a number of inter-related problems, including accelerated erosion of land area and stream banks, sedimentation of channels, increased flooding, increased potential for public health problems, deterioration of aesthetic quality, and degradation of water quality. To aid in characterizing urban runoff problems, it is convenient to divide the urban environment into two parts, existing and new.

Existing urban runoff problems are those resulting from developed urban areas, areas where structures and pavements are in place, population densities are high, and where drainage is accomplished primarily through man-made conveyances. New urban runoff problems are those associated with planned or future urban development. These are areas where man's encroachment is presently minimal and where drainage is essentially natural.

The objective of stormwater management, from the Agency's point of view, is to reduce the negative impact of runoff on water quality and the related problems to acceptable levels, at an acceptable cost. The four principal alternatives for stormwater management are (a) source controls, (b) collection system controls, (c) storage and treatment and (d) more complex approaches embodying elements of each of the preceding three. Examples of source controls include surface flow attenuation, erosion control and improved sanitation practices such as street cleaning. Collection system controls include inflow/infiltration control, temporarily increased line carrying and/or storage capacity, and sewer separation. Storage variations include concrete holding tanks, open basins, and various underground containers.

For existing urban areas, limited source controls such as street sweeping and other housekeeping techniques may be the only practical approaches. Source controls and collection system controls which emphasize storage for the purpose of attenuating the rate of runoff rather than for ultimate treatment probably make more sense physically and economically in newly developing areas, where their implementation coincides with the design and construction of new facilities.

BMP: The Preventive Approach to Urban Stormwater Management

The first two management approaches — source controls and collection system controls — constitute the essential elements of a "preventive" approach to urban stormwater management. They emphasize measures for reducing stormwater pollution either (a) within the drainage basin, before runoff accumulates and enters the sewer systems, or (b) through management and alteration of the collection system itself. As such, they both offer a range of alternatives to costly "after-the-fact" storage and treatment of collected stormwater runoff.

The preventive approach tends to focus on developing areas, rather than on already highly developed areas, where source controls and collection system controls can be implemented more efficiently and effectively, with less disruption. However, even in heavily urbanized areas, collection system controls designed to minimize overflows, leakage and ruptures can be very effective in reducing storm-related pollution. Also, source controls and collection system controls become more feasible alternatives in highly developed urban centers where major urban redevelopment occurs.

The preventive approach stresses maintenance of the existing ecological equilibrium in a watershed, by minimizing the impacts of man's intrusion and *preserving the watershed's existing runoff characteristics*. An important means for doing so involves flow attenuation, that is, controlling the quantity and rate of flow of urban runoff. Flow attenuation, in an hydrologic sense, means to increase the time of concentration and decrease the magnitude of the peak runoff. When runoff velocities are thus reduced, less pollutants are entrained and the degradation of water quality, mitigated. Also, less soil erosion results, again because runoff velocity is reduced and with it the erosion force. Large volumes of water are not allowed to accumulate at constrictions but instead flow at reduced rates over a longer period of time, thus reducing the possibility of flooding.

Preventive runoff management is thus a *multi-purpose approach*, with water quality being an important consideration but not the only one. Erosion control, flood control, water supply enhancement, protection of the public health and enhancement of recreational opportunities and aesthetic amenities are also important beneficial effects of flow attenuation. Publicly financed abatement programs directed primarily toward water quality have been difficult to justify economically; the preventive approach to urban stormwater management allows linkages with other environmental management objectives and programs, and promotes integrated, cost-effective solutions to multifaceted problems.

The cost-effectiveness of the preventive approach is enhanced because it emphasizes *less costly solutions*, i.e., comprehensive planning and local regulation in place of capital-intensive treatment facilities or, where facilities are required, smaller treatment facilities and relatively less expensive detention devices. Planning for spatial allocation of development can reduce runoff generation, as can public acquisition of open space and preservation of permeable areas. Regulations of certain types of land uses through establishment of performance standards can also reduce the generation and accumulation of runoff. Effective anti-litter ordinances, street cleaning services and infiltration/inflow controls can do much to reduce the treatment burden resulting from urban runoff. Flow attenuation techniques can slow the flow of significant amounts of stormwater into the sewers, and the cost of almost any system for abating storm sewer discharges and combined sewer overflow pollution is very sensitive to both the quantity and rate of flow involved. Dentention of runoff in impervious areas reduces the rate of flow and hence increases the period in which the same runoff volume can be treated. Retention of runoff in pervious areas can reduce the total flow that reaches the sewers by allowing additional groundwater recharge through percolation. Both techniques thus allow the construction of smaller treatment facilities and the realization of lower O & M expenses.

The preventive approach consists of a stance which urban areas can take toward their future growth and development. It postulates that urbanizing areas don't have to merely accept whatever development comes along, and simply collect and treat the resulting runoff as if it were raw sewage. Instead, they can either (a) directly regulate activities or (b) ensure that the development which does occur is accompanied by safeguards which will minimize the generation and accumulation of runoff.

This seminar is an initial effort in providing timely assistance in the form of appropriate technologies and management procedures to reduce pollution from urban runoff.

Considerations in Characterization
of
Urban Runoff
for
PL 92-500 Section 208 Planning

by

Francis J. Condon, P. E.
Office of Research and Development
Environmental Protection Agency
December 10, 1975

Considerations in Characterization
of
Urban Runoff
for
PL 92-500 Section 208 Planning

The information contained in this paper is mostly taken from published or soon-to-be published reports of the Environmental Protection Agency. The intent is to pull together the sections of these various reports which pertain to the topic of Consideration of Characterization.

When addressing this subject it should be kept in mind that there are three sources of urban runoff; combined sewer overflows, storm sewer discharges and overland or non-point runoff. Each has like and unlike elements in the consideration of characterization, impacts and remedial methods. The identification of each is also, to some degree, a function of the definitions chosen. The intent is not to become involved in defining and discussing each source but rather to present an overview which is applicable to Section 208 planning.

The principal types of planning programs now underway in water quality management can be grouped as follows:

1. Long range framework plans for coordinated management of resources over large areas, such as State water plans, State land-use plans and framework studies designated under Public Law 89-80, Section 102.
2. Medium range plans for identifying specific action for the development, protection and conservation of resources such as basin plans under Section 303(e) of PL 92-500, Section 208, Level B studies of Section 209 and specific functional plans for energy, transportation, land use and water resources.
3. Detailed site specific studies for facilities planning pursuant to Section 201, and evaluation of discharge permit applications.

Planners and managers responsible for the performance of the above and other types of planning programs must deal with the engineering, economic, financial, legal, institutional and environmental aspects of water quality. The detail required in the analysis of those aspects depends upon the planning purpose. Broad framework plans seldom require the detailed analysis appropriate to an areawide 208 waste treatment management plan, while a 208 investigation seldom requires the detailed engineering type data of a Section 201 plan. These and the next few observations are contained in the EPA report entitled "Cost Effectiveness of Water Quality Decision Methods - Water Quality Modeling Handbook for Planners," by Grimsiud, G.P., Finnomore, E.J., Owen, N.J. and Lewis, D. M.

One of the first crucial decisions encountered by planners and managers is selection of planning methodologies. The methods chosen should fit the situation and be capable of execution within the limits of time and budget. The selection of the planning methodologies must take into account the types of analyses needed and the number of analyses to be made. This means that the first task is a complete problem identification and description.

The full description of water quality problems or water quality component of problems requires identification of the location, nature, and magnitude of the pollution sources as well as the resulting impact on water quality. Preparation of a complete problem description may be relatively easy in the case of individual point sources of waste which have been or can be readily monitored and where ambient water quality changes can be directly related to specific effluent. In other and more complex cases, arriving at an adequate description of the problem may constitute a major portion of the planning process. In these more difficult cases, the water quality analyst, using modeling or other appropriate techniques, becomes a key member of the planning team.

Nonpoint sources of pollution occurring with variable severity throughout an area or different portions of an area and in conjunction with one another present a particularly difficult task for a planner. Component parts of such pollution loads must be identified and qualified in at least general terms. Otherwise, corrective actions are likely to to be proposed on a more or less arbitrary basis and without assurance or even a knowlegable estimate of their efficacy. The financial and social costs of pollution abatement measures are too large to permit such speculative planning. It falls then to the analyst and planner to set forth an analytical procedure which will remove the mask of complexity and enable clear understanding and description of the problem.

Once the problem is defined technical difficulties may be encountered in making 208 evaluations. These may include:

(a) the location, nature and extent of non-point sources;

(b) the complex biological, chemical and physical interactions which take place over time between land use, effluents, discharges and receiving waters;

(c) effects of various types and amounts of waste treatment upgrading or the generation and release of various pollutants which affect water quality; and

(d) water quality impacts resulting from modification of hydraulic regimes, land use, or other actions.

In addition to technical difficulties, the number of waste management alternatives which exist and require evaluation may be large. The complexity of water quality analyses and the need to investigate large number of alternatives has stimulated the development of a varity of tools ranging from simple graphical techniques to sophisticated computerized models. Whatever the tool chosen one should know the site specific characteristics and impacts of urban runoff within the context of the 208 area land use, the receiving water characteristics and the planning method used.

Hence we arrive at our subject - Consideration in Characterization of Urban Runoff.

This subject can be interpreted in many ways. When addressing it the scope is so broad as to be almost overwhelming. Many aspects deserve much more time than can be given here. However, all of the elements mentioned will be covered in more detail by other speakers. This presentation is intended to give an idea of what should be considered in characterization. Therefore, the discussion will focus on the more pertinent elements and utilize a skeleton form of presentation.

The first topic in discussing Characterization is: "Why Data Are Necessary." This topic is fraught with possibilities. Immediate variants of this theme could be: "What data are needed for problem definition," or, "Why reliable site-specific data are necessary;" or, "What the weaknesses of existing data are;" or, "How best can scientific data be communicated to the planner users" and continuing on for any number of subtopics.

The following observations highlight some of these variants of "Why Data Are Necessary."

The approach chosen is to paraphase or quote nationally known experts or publications and then add some thoughts from personal experience.

1. Wallace and Dague in a paper published in the J. WPCF in 1973 said the determination of the effects of land runoff on water quality is a complex problem and was suited to mathematical modeling. They then pointed out the difficulties in achieving accurate modeling results. These are verified land and river hydrologic data, pollutant characteristics and receiving water quality data. As an aside one can say that covers most of everything.

2. Whipple et al in the Journal in 1974 said that only data that are systematically gathered and classified with respect to population, industrial activity and hydrologic background can be expected to be useful for planning purposes. At a minimum I would add land use and the drainage system.

3. Terstreip and Stall in reporting on the Illudas that is, the Illinois Urban Drainage Area Similator, in a paper given at the National Symposium on Urban Rainfall and Runoff and Sediment Control in 1974 said, and this is a quote, "The present limited amount of urban hydrologic data is a serious deterrent to development and testing of storm runoff models. It seems unlikely that any significant improvement in current models is possible until more data and better quality data are available." End of quote.

4. An article in the December 1973 Diplomate after summarizing a portion of known data concluded that reliable knowledge of storm patterns over urban areas and the associated runoff pollutant characteristics is most important on a site specific basis. Emphasis was placed on the fact that the engineering significance of such data for pollution assessment and remedy was great. It went on to say that rain gage networks and sampling programs to determine pollution loads and receiving water impacts for planning and determining abatement measures, if required, are necessary.

5. Barter and Sherrill of the University of Michigan in their report "Rainfall-Runoff Relations on Urban and Rural Areas" noted that there were a number of basins which did not follow the expected runoff pattern when basin size and population density were taken into account. They went on to conclude that perhaps the differences could be explained if more were known of the density and efficiency of the drainage system and the related land use. They suggested that some measure of drainage efficiency could be used in place of population density as a measure of urbanization.

6. A recent publication entitled "A Practical Framework for River-Quality Assessment," Geological Survey Circular 715-A by Rickert and Hines sums up nicely why data are necessary. A resume of some of the points made in that booklet are as follows:

(a) The tendency today is to conduct river quality assessments solely on the basis of existing data. This approach is mostly ineffective, because existing data are seldom adequate to support intensive assessment of multiple problems.

(b) Correlative data on hydrology and especially waste discharges are seldom determined. As a result, most monitoring and surveillance data indicate effects rather than give insight into causes.

(c) Monitoring programs usually collect limited grab samples at widely dispersed sites under a variety of conditions. Such data rarely provide quantitative knowledge.

(d) The relation between riverflow and time of travel is seldom known or is overlooked in the planning of monitoring programs.

(e) The inherent sampling and analysis errors for river quality variables are relative large. A number of sample sets are necessary to define a range of error as a index of inherent variability.

(f) Each new study will be faced with collecting information to fit specific needs not covered by existing data.

(g) Useful assessment requires a mutual understanding between the resource scientist or engineer and the planner. The scientist needs to assess in the context of planners requirements, and the planner needs to understand the meaning and implications of the scientist's findings. Most environmental assessment tend to be unilateral. (My comment is that Section 208 planning studies provide the vehicle for cooperative ventures).

This is enough to make the point that more base data are necessary. You will note that data are required across the entire spectrum. Site specific rainfall runoff relations, land use, runoff systems, discharge characteristics, and receiving water hydrology and impacts, have all been identified as lacking reliable data for engineering type assessments.

Given this litany of needs, where does one start? Based on our program experience it is strongly recommended that at the earliest date possible a rain gage network be made operative in the area(s) under study. This is one of the most needed and easiest information requirements.

If data are to be collected these are the minimum conditions which must be met.

(a) Measurements of runoff characteristics and impacts are useful only with respect to their relationships with each other and with associated conditions.

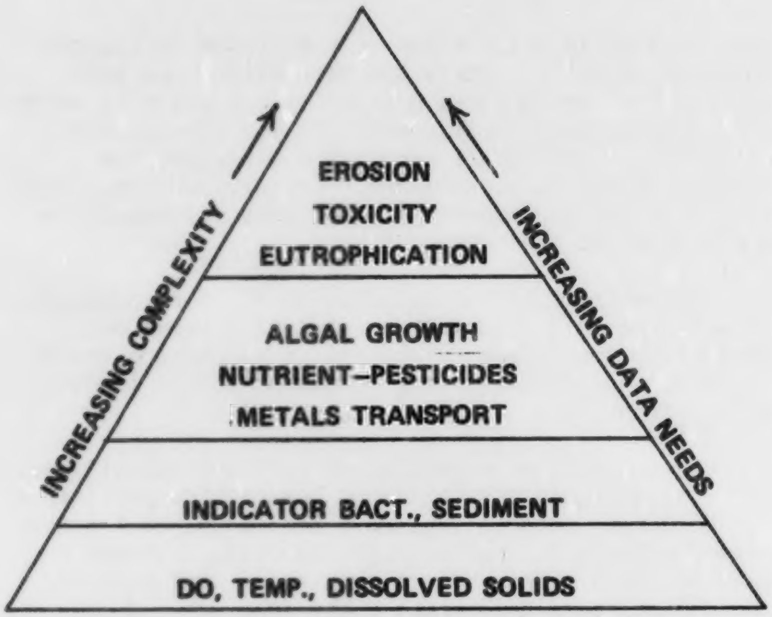
(b) Flow measuring is as critical as flow sampling.

(c) There must be sufficient base knowledge along with real time data collection of the receiving water conditions and hydrology. This is an often underestimated data need.

(d) There must be reasonably accurate urban hydrologic and land use data.

(e) Any study on impacts must be based on comprehensive, integrated assessments of present and future land and water use.

(f) Finally and most importantly there must be time synchronous data on rainfall, runoff hydrology, runoff characteristics and receiving water conditions and hydrology.


INCREASING COMPLEXITY
INCREASING DATA NEEDS
EROSION
TOXICITY
EUTROPHICATION
ALGAL GROWTH
NUTRIENT–PESTICIDES
METALS TRANSPORT
INDICATOR BACT., SEDIMENT
DO, TEMP., DISSOLVED SOLIDS

RELATIVE DIFFICULTY OF APPLIED MODELING FROM "A PRACTICAL FRAMEWORK FOR RIVER QUALITY ASSESSMENT" BY D.A. RICKERT AND W. G. HINES. GEOLOGICAL SURVEY CIRCULAR 715–A

An observation on the length of time of such data gathering is in order. In a statistical evaluation of rain events done by NOAA one of the findings was that 85 percent of the various intensity and duration rain events for a given location will be experienced in 2.8 years. This is with 90 percent confidence. Therefore, in our storm and combined sewer program we maintain that a minimum of three years of data collection on rainfall, runoff loads and receiving water impact are necessary. This does not necessarily mean every runoff event is sampled. A statistically selected number of events per season over a three year period may be sufficient.

Additional reasons on the necessity of base data are the author's observations. The following points are specific to urbanized areas and are based on work done in the EPA R&D program. Firstly, we know generally the daily deposition rates of pollutants on urban surfaces as a function of traffic and land use. We also have developed a surface sampling procedure for pollutant loading in which there is reasonable reproduceability. Secondly, there has been effort put into determining the "pollution storm" (that rainfall which will produce measurable runoff for various surface conditions), the runoff return frequency and the "design storm" runoff volumes. Thirdly, we have knowledge of, and have developed, mathematical models for application to storm water runoff.

But where data is needed is in the determination of site specific pollutant accumulation rates as opposed to deposition rates, and of equal importance is the determination of the pollutant runoff loading attenuation factor.

In the work we have done we have not established, with reliability, the relations between the pollutants on the urban surfaces available for flush and the mass emission being discharged from the outfall in wet weather flows. We have not obtained a mass balance. The generalities hold true: dirty land use - dirty runoff, parking lots worse than roadways, uncontrolled surface modification - heavy sediment loads, and so on. But we haven't been able to repeatedly predict a given pollutant runoff load as a function of surface samples.

This non-relationship may be caused by the attenuation of some pollutants as they are transported from the surface to the discharge. The sediments loads are sometimes higher than predicted while BOD is less. The failure may be in the flow sampling and measuring techniques. Or, it may be in the peculiarities (hydrologic and otherwise) of a given collection-transport system. We don't know. The only aspect we are sure of is that site specific runoff and characterization data gathering is necessary if remedial decisions based on quantitative data are to be made.

Lastly, the most important point of all is that we have no nationally verified data of the impacts on receiving waters caused by urban runoff. There is base information need for: (a) the seasonal differences, (b) the different types of receiving waters, (c) the different flow regimes, and (d) the key pollutant determinations.

Up to this point the discussion has pointed out the deficiencies. This is so because the needs numerated are at the quantitative level. If the goal of a given 208 study is principally to provide managerial and planning guidance then the outlook is somewhat brighter.

EPA and others have provided, and in the near future will provide more, data and information which can be used in the qualitative sense.

Through the various mathematical models including the EPA developed Stormwater Management Model, and reports such as "Contributions of Urban Roadway Usage to Water Pollution," "Urban Stormwater Management and Technology - An Assessment" "Water Quality Mrnagement for Urban Runoff," and "User's Handbook for Assessment of Water Pollution From Non-Point Sources," we have provided a foundation upon which the engineer-scientist can build a specific qualitative method for a timely preliminary assessment of the cause and effects of runoff pollution. From this point the planners, engineers and scientist together can then develop a program for conducting further work to upgrade assessments to the quantitative level.

In this vein I will make a suggestion for your consideration. The original Water Pollution Control Act of 1956 provided for Comprehensive River Basin Studies. These studies were carried out from 1956 to 1960. Large amounts of receiving water data were gathered. Perhaps, if one were to obtain old land use maps, stream flow data and precipitation records, and couple these with the River Basin studies findings and now available data a leg up on qualitative assessment would be gained.

The qualitative assessments which can be obtained through the 208 program will be highly valuable to the decision making process. This leads us into the second topic of Characterization Considerations. That is, "Sampling Procedures."

In this short discussion let us straight away disperse with any hang-up on the point versus non-point source definitions. We have to have a channel or containment of some sort in which to place the sampler.

Whether it is a ditch, pipe, gutter, gully, stilling tank or whatever the sampling has to be done at a point. Despite legislative definitions most urban runoff enters receiving waters at a point. The user can decide if the discharges meet point or non-point criteria. Therefore, it matters not in terms of the following discussion if your concern is point or non-point. To further limit the subject we will not address here sampling procedures in receiving waters.

The following base-line conclusions on procedures are derived from available or soon to be published EPA reports of our program. These are "Recommended Procedures for the Conduct of Storm Generated Discharge Projects," "Collection of Field Data for Stormwater Model Calibration," and "Nationwide Characterization, Impacts and Critical Evaluation of Stormwater Discharges, Combined Sewer Overflows and Non-Sewered Urban Runoff."

1. An automatic liquid sampler is one tool of several that must be employed for the characterization of runoff. Grab or random samples have little application in storm generated runoff. The selection of the sampler must be based on the consideration of the overall sampling program, the characteristics of the flow to be sampled, the physical characteristics of the sampling sites, and the analyses that are desired.

2. In view of the large number of highly variable parameters, no single automatic sampler can exist that is universally applicable with equal efficacy. Some requirements are conflicting, and careful trade-off studies are required in order to arrive at a "best" equipment selection for a particular program. A systems approach is required for either the choice or design of automatic sampling equipment in application to runoff.

3. The proper selection of the sampling site can be as important as the selection of the sampling methods and equipment. A clear understanding of the data use requirements is necessary as is familarity of the basin to be evaluated.

4. Specifications of equipment to be given careful consideration are: intake design, specimen intake and transport velocity, line size, and sample capacity.

5. The most common problems in field use of samplers are: leaks in vaccum operated units, faulty automatic starters, inlet blockage, line pluging, limited suction lift, low transport velocities, complicated electrical systems, and failure of timers, micro switches, relays, contacts and reed switches.

6. The greatest problem is the selection or design of a sampler intake that can gather a representative sample, even in stratified flow conditions, and at the same time be relatively invulnerable to clogging or damage due to solids or debris in the flow stream.

7. In-situ monitoring, at this time, is not recommended to replace analytical laboratory measures. In situ monitors can be used for determining changes in characteristics once reliable relationships between runoff parameters are established.

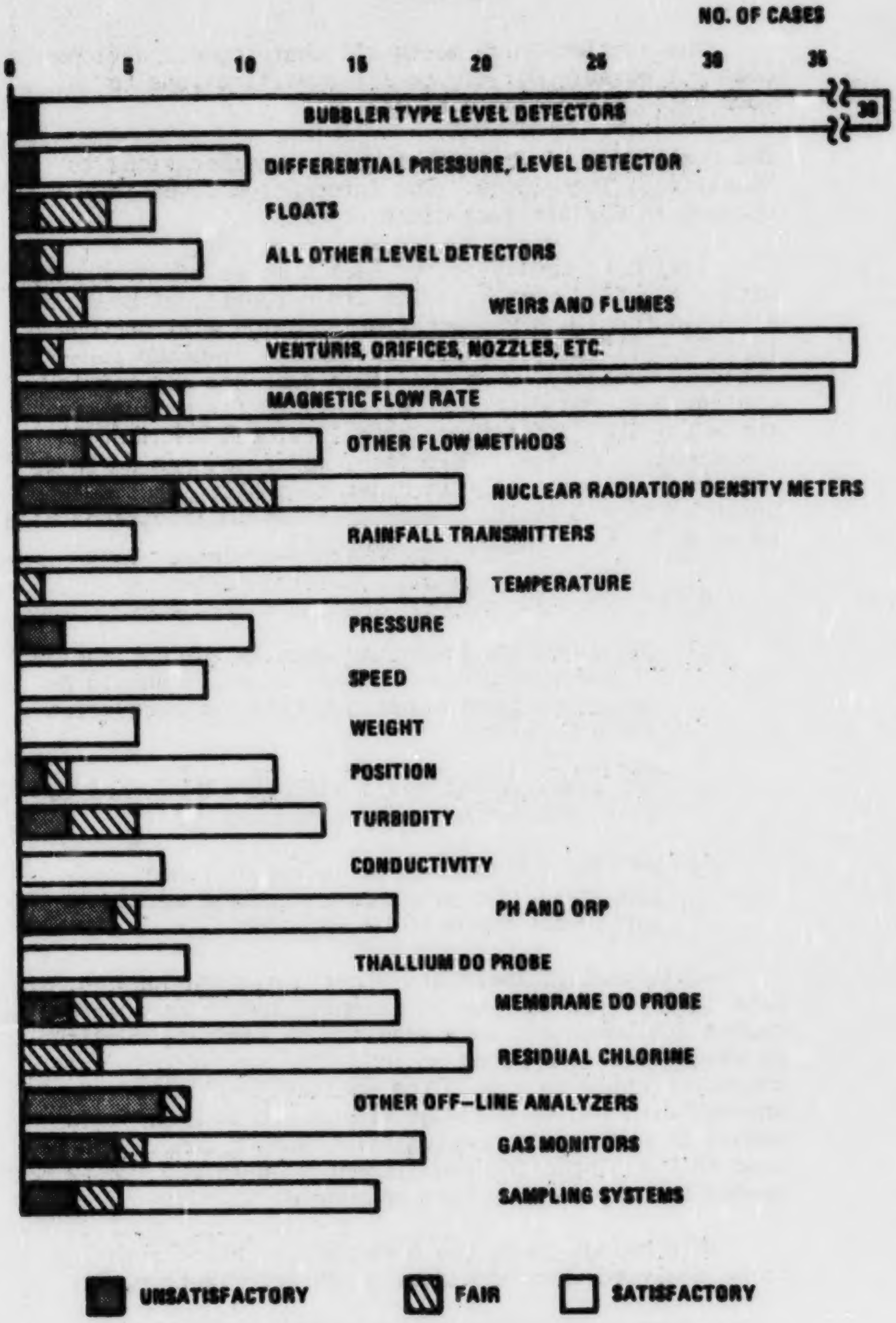
8. Flow measuring rivals sample taking in importance. Devices for gaging wet weather flows vary in complexity from a dipstick or chalked length of rope to sophisticated electromechanical and electronic instruments. Float gages and bubble tubes have found most common use to date. Ultrasonic level gages and bubble tubes have found most common use to date. Conductivity or dipper gages are gaining in use for storm generaged discharges.

In summary the desirable procedures and sampler characteristics are:

- The ability to take a sequential timed series of discrete samples.
- Use an external signal to allow sample frequency (volume) to be taken proportion to flow rate or increments of flows.

- Four different sample containers should be filled at each sampling:
  - a) one for solids and BOD testing to hold no presentatives
  - b) one for metals and TOD analysis, acid added to preserve samples.
  - c) one for nitrogen and phosphorus, $HgCl_2$ mercuric chlorine, added.
  - d) a sterilized container for bacteria analysis, or grease and oil, or other tests.
- A capability of handling 2000 cc containers.
- Capability of programming the time interval. Short sampling intervals in early stages or runoff, longer intervals as storm continues.
- Capability to hold 96 sample containers.
- Refrigeration capability to hold samples at 4 C.
- Capability of lifting the specimen 25 ft. or more without affecting sample size.
- Have a self contained power source.
- Be automatically activated and sample at the beginning of runoff.
- Inlet line sufficiently large to eliminate plugging.
- Inlet sampling velocity sufficiently high to keep heavy particles in suspension.
- Inlet of such configuration to allow representative samples.
- Inlet to be self cleaning and the capability to purge sample lines.

INSTRUMENTATION PERFORMANCE
50 TREATMENT FACILITIES
1972–1973



FROM EPA DRAFT REPORT "INSTRUMENTATION AUTOMATION EXPERIENCE IN 50 TREATMENT FACILITIES" BY MOLVAR A. J., ROSLER J. F., WISE R. H., BABCOCK R.

The sampler which meets all these specifications does not exist. But try to fit specifications to your more critical conditions.

The next topic of Characterization Considerations is "Analytical Techniques. The information given is covered in the previous cited reports.

I wish to emphasize the fact that we are confronted with a two fold problem. The urban runoff, although in a liquid form, has characteristics which will prevent reproducibility of results for certain standard parameters. Secondly, when the urban surfaces are sampled the dry dust and dirt must be analyzed for pollutants for which standard methods were developed considering a wastewater medium. Therefore, modifications to these methods have to be made in order to analyze particulate urban surface deposits. Most of these modifications need to be further evaluated and improved.

A few specific examples are:

a) the digestion procedure used in the estimation of heavy metals in roadway deposits should be tested to insure that quantitative recoveries are achieved.

b) the inability of the classical BOD method to deal with these types of samples.

c) methods for the determination of rubber and asbestos. The asbestos analytical method in particular needs to be upgraded.

Additionally, there are other considerations in data interpretation. As an example, indicator coliform counts are important in assessing the sanitary quality of wastewaters and water bodies. The use of this same characteristics to assess the sanitary quality of runoff unmixed with sanitary sewage from an urban area could result in misleading conclusions. Such a conclusion may lead to a disinfecting requirement when in fact it is not needed and may do more harm than good.

This brings us to the more useful characteristics to be analyzed when considering characterization. If we considered all the organic and inorganic compounds which can be available for flushing the list of possibilities would be near endless. Therefore, let us consider the fundamentals.

The following are usually the more important classifications.

1. Oxygen Demand - It is universally accepted that the dissolved oxygen concentration in the receiving water is a critical criteria in water quality.

2. Particulate Concentration - In urban runoff particulates are a large fraction of the total solids. Suspended solids and turbidity are critical in water quality.

3. Pathogenic Indicators - Although a classic criteria the coliform group is not necessarily a sensitive indicator of pathogenicity as far as urban runoff is concerned. However, this is a critical parameter if combined sewage or treatment plant by-pass is to be considered.

4. Eutrophic Potential - The principal nutrient and trace salts are critical criteria in most water quality evaluations.

5. Toxicants - In urban runoff this is of special interest. Some toxicants can directly affect man (asbestos, lead) while others can have deleterious effects on the aquatic biota. The toxicants can be put in the general categories of heavy metals, pesticides, herbicides and exotic chemical compounds.

6. In addition to the water quality criteria there are a number of simple analyses which can be used to describe the physical state or condition of storm discharges. These are pH, temperature, conductivity, color, odor, oils and grease among others.

To determine these minimum characteristics the following specific analyses are suggested for urban runoff.

The oxygen demand indicator should indicate the effect of the addition of the discharge or, the oxygen content in the receiving water. That is, it should give an indication of the total oxygen demand on the water. Additionally, the method should have a standard procedure and precision so that valid comparisons can be made for discharges entering widely different receiving waters.

After weighing the advantages and disadvantages of the various oxygen demand test, and the accepted usage, it is suggested that two tests be run. These are TOD and BOD . The BOD test may require minor modifications. Even though it is not convenient to run both tests as an estimate of a single parameter the importance of oxygen demand needs special consideration.

The suggested measurement of particulate concentration is influenced by the tremendous array of particulate solids carried in stormwater discharges. To stay out of trouble and for the purpose of this discussion, particulate matter is defined as solids which are retained on a filter medium upon passage of a sample,

The broad categories of particulates are organic and inorganic. Runoff has a large amount of inorganics. But even giving this does not preclude a tremendous variation at any particular outfall. It is difficult to predict the concentrations of particulate matter which one can expect.

Considering the advantages and disadvantages of the various residue tests, it is suggested that the suspended residue be used. The analysis is considered routine and is not time consuming and if need be additional steps can give the fixed and volatile portion. The selection of additional tests is dependent on the kind of data required.

The pathogenic indicator is required with the above noted cautions. A complicating factor is that there are many illegal connections and disdischarges of sanitary and industrial sewage into runoff drainage networks. The fecal coliform indicator system is the superior one at the present time for assessing the sanitary quality of these flows. While careful laboratory techniques should be exercised, it is apparent that with the high counts, high precision is not required. It would be an unnecessary expense. It is suggested that the MF techniques be employed for conducting fecal coliform counts. A careful survey or diagnosis of the stormwater runoff system for the illegal connections is also in order.

The eutrophication potential has probably received more attention in the last 15 years than any other water resource problem. Eutrophication is a natural process but man's activities can greatly increase the rate. At the present time the runoff eutrophication potential is best determined by the nitrogen and phosphorus

It is suggested that basically two nitrogen analyses be conducted. The first for total oxidized forms of nitrogens, that is, the sum of nitrite and nitrate. The second nitrogen analysis would be for the reduced forms of nitrogen. For this is is suggested that the Kjeldahl procedure is used. It is further recommended that both oxidized and reduced nitrogen analyses be expressed in terms of weight of nitrogen rather than individual ions. This way you can add the two values for total nitrogen content.

The phosphate ion can occur in a variety of soluable and insoluable inorganic compounds. It can also occur in both living and dead organic matter. It is recommended that total phosphorus analysis be conducted where impact on receiving water is of concern. In some investigations it has been shown that analyzing for soluable phosphate alone can result in erroneous low conclusions. Therefore, it would be helpful to run both total soluable phosphate and total phospheous. To repeat, the two analyses for nitrogen content are total Kjeldahl and total oxidized. For phosphorus it is the total phosphorus analysis.

The discussion of analyses for toxicants will not be detailed. Heavy metal analysis should be done by atomic adsorption spectroscopy. It is suggested that first composite samples of the runoff be run for lead, zinc, copper, chromium, mercury, cadium, arsenic, nickel, and tin. Then based on the results one can make a decision on what and how often discrete or other composite analyses will be necessary. Certain industrial land uses or street salting practices can be circumstances where determination of uncommon parameters may be desirable.

In heavy metals, evaluation of the toxic potential requires that the total amount of the heavy metal be determined. In some cases it may be necessary to determine the chemical form of a given heavy metal. Therefore, because of the organics present, samples should be digested prior to analysis.

Because of the controversy over pesticides and polychlorinated biphenyls they do merit special attention. No pesticide or associated compounds are recommended for urban runoff routine analysis. However, a study of the drainage area is necessary to determine the likelihood of pesticide in the discharges. This will determine the frequency and season for testing. A search type of random selection for PCB analysis should be done early in the evaluation.

There can be a number of pollutants and contaminants in runoff which are not normally identified in determining degradation but which may be significant on a site specific basis. Some of these are asbestos, rubber, asphaltic materials, oils and grease and sulfates. Analytical techniques for most of these are undergoing change. One will need to keep abreast of the literature.

In summary the minimum descrete routine analysis are:

Potential Oxygen Demand	by TOD and BOD_5
Particulate Concentration	by Suspended Solids
Pathogenic Indicators	by Fecal Coliform
Eutrophication Potential	by Total Oxidized Nitrogen, Total Reduced Nitrogen and Total Phosphorus

Other suggested characteristics - Ph and Conductivity

Flow gaging has been the subject of considerable R&D effort in industry, government and universities for the last several years. Despite this, in terms of the runoff conditions and requirements, flow measurement is still our most difficult problem.

A procedure will not be given for flow measuring.

This is discussed in detail in the paper "Collection of Field Data for Stormwater Model Calibration" by Phillip E. Shelly. The site, the physical conditions, the data desired, and a host of other considerations go into selecting or designing the flow measuring method.

The foregoing are the principal points I wish to make in sampling procedures. At this juncture a few words on sample compositing and descrete samples would be worthwhile. Discrete samples should be taken on the first sampling runs to establish, if possible, concentration patterns. They should at least be taken in the early periods of runoff events. When to begin compositing will depend on many factors: Observed trends, economics, needed detail, laboratory capacity available and other considerations.

Under most conditions the best composite method is where the volume is proportional to the instantaneous flow rate. However, with the exception of the simple composite, the difference in results in urban runoff are not large between the various proportioning methods.

The subject of compositing is treated in learned papers, an indepth recitation is not appropriate here. The point being made is that both flow measurements and a knowledge of the temporal variation of pollutants are required to determine the loads and corresponding impacts, and possible remedial measures.

The last subject in Characterization Considerations is Mathematical Modeling. This is not to imply that mathematical models are required to carry out a 208 Plan, but in most instances it will be an importanmt tool.

Mathematical simulation models, when used properly and with an understanding of their limitations, can greatly expand the range of alternatives a planner may consider and assist in providing information in an organized form. It should be stressed, however, that such models are nothing but tools to assist planners in the difficult task of evaluating alternatives. They are not a substitute for experience and good judgement, but a means for permitting these qualities to be used more effectively.

Eighteen mathematical models for the nonsteady simulation of runoff in urban storm and combined sewerage systems were reviewed in a study sponsored by the U.S. Environmental Protection Agency entitled "Evaluation of Mathematical Models for Engineering Assessment Control, Planning, and Design of Storm and Combined Sewerage System." The models were evaluated on the basis of information published by the model builders and model users. Seven models were also tested by computer runs using both hypothetical and real catchment data. Most of the models evaluated include the nonsteady simulation of the rainfall-runoff process and flow routing in sewers; a few also include the simulation of wastewater quality options for dimensioning sewerage system components, and features for realtime control of overflows during rain storms.

All of the 18 reviewed mathematical models are suitable for the simulation of storm and combined sewerage systems or for incorporation in comprehensive simulation models. Considerable differences exist, however, in the types of phenomena that are modeled and in the mathematical formulations for each phenomenon. The report summarize the objectives, advantages and limitations of each model. For some applications models are available with considerable simplifications in their mathematical detail to reduce input data requirements, computer storage requirements, and computer running time. Some models include unnecessary approximations considering present state-of-the-art of hydrologic modeling and computer capability. Some of the simplifications, however, are based on the need for realtime control of overflows using a small process computer with slow execution times but the requirements of repeated simulations within fixed time constraints.

The models were evaluated on the basis of published information and communication with model developers. In addition, seven of the more comprehensive models were selected for testing by computer runs using hypothetical and real catrchment data.

In selecting these models, a minimum requirements was the capability to consider several rain guages, to compute runoff from several catchments, and to route flows in a converging branch sewer network. Models which rely heavily on mathematical formulations which cannot be derived readily from catchment and sewer physical characteristics were not tested, nor were more models whose oversimplification restricts their use unnecessarily, considering present computer capabilities and the state-of-the-art of hydrologic modeling.

The 11 models which were evaluated solely on the basis of published information in reports by model users are:

1) British Road Research Laboratory (BRRL) Model
2) Chicago Hydrograph Method
3) Colorado State University Urban Runoff Modeling
4) Corps of Engineers Hydrologic Engineering Center Storage, Treatment, Overflow and Runoff Model (Storm)
5) Hydrocomp Simulation Program
6) Minneapolis-St. Paul Urban Runoff Model
7) Seattle Computer Augmented Treatment and Disposal System
8) University of Cinncinnati Urban Runoff Model
9) University of Illinois Storm Sewer System Simulation Model
10) University of Massachusetts Combined Sewer Control Simulation Model
11) Wilsey & Ham Urban Watershed System

The seven models which were also tested by computer runs are:

1) Battelle Urban Wastewater Management Model
2) Dorsch Consult Hydrograph-Volume Method
3) Environmental Protection Agency Storm Water Management Model (SWMM)

4) Massachusetts Insitute of Technology Urban Watershed Model

5) Metropolitan Sanitary District Greater Chicago Flow Simulation Program

6) SOGREAH Lopped Sewer Model

7) Water Resources Engineers Storm Water Management Model

A review of all 18 models and preliminary results of the numerical testing of four models is presented in the report by Mr. A. Brandstetter.

No single general mathematical model exists that can simulate all aspects of water quality. Furthermore, it is not clear that such a model should be developed. Its resulting complexity, assuming that it could be created, the amount of data needed to validate it, and the cost of operation would likely make its use impractical. Instead, a wide variety of specialized models have been developed to efficiently handle particular aspects of water quality of interest to planners. From the planner's viewpoint, models can be classified by their applicability to various parts of a hydrologic system, the effects simulated by the model, and the method of analysis.

In summary, for 208 Planning ---

1. The first step is to define the problem and determine both what information is needed and what questions need to be answered. Remember! The impact on the receiving water in terms of violations of desired use and water quality standards is the nut.
2. Use the simplest method that can provide the answers to your questions.
3. Use the simplest model that will yield adequate accuracy.
4. Do not try to fit the problem to a model, but select a model that fits the problem.
5. Do not confuse complexity with accuracy.

6. Always question whether increased accuracy is worth the increased effort and cost.
7. Do not forget the assumptions underlying the model used, and do not read more significance into the simulation results than is actually there.

In closing a useable plan at decision time is worth far more than an excellent one that is late.

Partial List of EPA Storm and Combined Sewer Reports Applicable to Section 208 Planning not noted in Text.

1. EPA-440/9-75-004 "Water Quality Management Planning for Urban Runoff." NTIS PB 241 689/AS.

2. EPA-6709/2-75-065 "Short Course Proceedings Applications of Stormwater Management Models" NTIS - Pending.

3. EPA-670/2-75-046 "Rainfall-Runoff Relations on Urban and Rural Areas" NTIS PB 242 830/AS $5.25.

4. EPA-600/2-75-004 "Contributions of Urban Roadway Usage to Water Pollution" NTIS - Pending

5. EPA-R-2-73-261 "An Assessment of Automatic Sewer Flow Samplers" GPO Bookstore $2.25, NTIS PB 223 355 $2.60

6. EPA-670-75-041 "Storm Water Management Model: Dissemination and User Assistant" NTIS 242 544/AS $4.25

7. EPA-660/3-74-020 "Estimating Nutrient Loading of Lakes from Non-Point Sources" NTIS PB 238 355/AS $3.90

8. EPA-670/2-75-022 "Urban Stormwater Management Modeling and Decision Making" PB 242 290/AS $7.00

9. EPA-670/2-74-096 "Characterization and Treatment of Urban Land Runoff PB 240 987/AS $6.20

10. EPA-600/2-75-007 "Impact of Hydrologic Modifications on Water Quality" NTIS - Pending

11. EPA-600/4-75-001 "Director of EPA, State and Local Environmental Quality Monitoring and Assessment Activities" Office of Monitoring Systems, EPA Washington

12. EPA-600/5-75-005 "Performance Control for Sensitive Land: A Practical Guide for Local Administrators"

13. EPA-907/9-74-005 "Wastewater Sampling Methodology and Flow Measurement Techniques" by EPA Surveillance and Analysis Division, Technical Support Branch, Field Investigation Section

QUESTIONS AND ANSWERS

(Following Francis Condon's paper "Characterization of Urban Stormwater Problems")

Question (Arthur Jenke, Alamo Area Council of Governments, San Antonio, Texas): The author of the USGS Circular 715A said that we need more data. Actually, we have no time to collect this additional data. As far as performance in the 208 area is concerned, we have approximately 20 months. We must use the data that we have now. Do you have any response to this?

Condon: Yes. You are right and, unfortunately, all of us are right. The item that I was addressing is quantitative data. This is needed and, in a way, it is needed to fulfill the requirements of the Act. As you said, the Act didn't give you enough time. There is enough data, I believe, to make qualitative assessments. Soon EPA will have available a User's Handbook giving loading factors for land use. There is also available the EPA Stormwater Management Model. EPA has put on short courses in the use of mathematical models and others are planned.

Question (John Fisher, Consulting Engr., South Bend, Ind.): I share Mr. Jenke's views about the timing on the 208 Program. I would like to share a few other points with the 208 people here. We are working on a 208 Program in Western Michigan, which includes the Grand Rapids area. Because of the funding formulas which were used, there is not only a time problem but also a dollar problem in developing an adequate sampling program. So, we had to cut back somewhat and rely on existing data--STORET data or other programs such as the Corps of Engineers Urban Studies Programs, some of the U.S.G.S. sampling programs, and the SCS sampling that has been underway for a number of years. What I propose is to set up a simple network of the 208 agencies to share the monitoring or water quality data gethering information being developed by them. This would be a simplified data bank. The outputs might be 8½" x 11", one-page summaries of the monitoring program--giving the frequency of sampling, the constituents being sampled, the period of record, variation in flow measurement, the drainage area, land-use classifications that are involved, et cetera. These summaries could be prepared for use by 208 agencies that can't afford, or don't have the time, to pursue sampling as they would like to do.

Condon: I think that your suggestion is very good. Timely exchanges of information is very important. We have some R & D reports coming soon dealing with characterization and impacts. But, I think that an exchange of hot-line information such as you suggested would be good.

Comment (John Kingscott, EPA, Washington, D.C.): We have been very aware that there is a need for lateral exchange of information as it becomes available. We have taken some steps to formalize an information exchange program where output reports from 208 agencies, as they are finished, can be published and distributed to other 208 agencies. There is a need for some specialized information. The problem with this particular program is that it waits until the reports are published in a final draft form before they are distributed. The output will be available toward the end of the planning period. We have to devise some system that will rely on the cooperation of each 208 agency to give us informal information as it becomes available so that we can distribute it. I don't see a problem so much with the mechanism. But, there will have to be a cooperative spirit on the part of each 208 agency to volunteer information as it becomes available.

Condon: Sometimes when you try to disseminate information fast you may put out incorrect information, because it often hasn't been verified. Once it gets in the literature, it's gospel and anything you try to do later to change it seems to make matters worse.

Comment (John Kingscott): There would have to be some kind of dialog established between 208 people and EPA people through face-to-face contact for such a program to work. Otherwise, use of the information may be dangerous. It would have to be worked over.

Comment (Paul Ferraro, EPA Region VIII): My question is how much data we need in order to make decisions. We seem to be skirting around the issue here. As the 208 Coordinator for Region VIII, I am interested in knowing what we need. We all mention the constraints that we have. There are dollar and time constraints. How do we get around this to set up a system that will answer the needs? I can cite an example of what we did in one case in Region VIII. We have three lakes where we plan to install a system to handle point-sources. We suspect there is also a non-point source problem. It doesn't relate to urban runoff directly, but it was from an urbanized area. We made an intensive, two-week survey during the runoff periods. We surveyed about once a week during the summer and then came back during the low flow in the autumn. So with a few weeks of data gathering, we were able to assess that we did have a serious non-point problem and that a solution to the point-source problem was not going to buy us much without looking at the non-point source problem. I wonder if there are other examples.

Condon: Solutions to such problems are site-specific. I'll give you an example. NOAH said (that's the National Air and Space agency--whatever they are called) that, with 90% confidence, a given area will experience in 2.8 years 85% of the kind of rain and snowfall events that it will ever experience. So, we always said that we need three years of data collection but we would go for two. That's part of the answer to the question of how much data collection is needed. The other part of the answer is that you don't have to sample and collect data on every storm event. It is random, but you can do a statistical analysis where you can pick out data for the four seasons. The seasonal variance is the big problem for most of the country. From past records you can try to get data on the variability of the hydrology of your receiving water. You can build yourself a little statistical analysis that tells you how many storms to sample and how many sampling runs to make. But, I can't give you a flat answer --because we are dealing with the whole country, having different rainfall-runoff relationships, different kinds of receiving waters, and different key pollutants. I don't know if anyone can provide an answer to this for the entire country--unless they put out a huge publication. It depends upon the depth of analysis that you wish to make. As someone said this morning, it is an "endless well". You could sample forever!

Comment (Rod Stroope, Seattle Metro): I am concerned about our discussion of data collection because it was centered on trying to identify the problem. I would like to point out the point of view in our area concerning the 1983 goals and the subjective elements that are input toward these goals. The problem is something that is not, necessarily, easily quantified in terms of collected data. Identifying the particular pollutants and their sources isn't going to be too difficult. Where I think we will have the most difficulty is in formulating solutions, especially non-structural solutions...... We will have difficulty in getting politicians to stand behind our solutions unless we can show the benefits that can occur. That's where I think we will get into a real bind. So, there is a dichotomy between collecting a lot of data in the beginning and, alternatively, merely trying to identify the real problems and anticipate where it will be necessary to sample data from several areas where you might be able to correlate the solutions--say, between non-urbanized areas and urbanized areas.

Condon: There are a couple of dichotomies there. I wasn't arguing with Paul (Ferraro). I was trying to support him by showing that there is a wide diversity of things. The one dichotomy that you brought up was that you have to tell the decision makers precisely what the effects are of these regulations that may be adopted for regulating the release rates of stormwater from a given parcel of property. You can do that only with some long-term sampling alongside of control areas. That kind of data would certainly require a long time for collection.

LAND USE AND URBAN DEVELOPMENT AFFECTING STORMWATER POLLUTION AND WATER QUALITY

by

Herbert G. Poertner
Engineering and Research Consultant
Bolingbrook, Illinois

WATER QUALITY STUDIES

The principal objective in water quality studies is to relate the in-stream water quality and pollutant concentrations to pollutant discharges from both point and non-point sources, at selected points along a stream, and estimate the impact of the discharges on water quality. To accomplish this, one alternative is to make programmed, physical and chemical measurements of in-stream water quality and mass pollution emissions of discharges at selected sampling stations. Concurrent measurements of stream flow and stage would also be taken. Without the benefit of other correlated information that can be used for predicting changes in water quality as a function of variable parameters that affect water quality, the measurements would need to be taken at scheduled intervals in a continuous program. Obviously, this would be prohibitively expensive and impractical when viewed with a nationwide perspective.

A more practical solution is to broaden such a study program in an attempt to develop correlations for each tributary watershed, between measured in-stream water quality and pollutant discharges with other measured data, such as: rainfall intensities and patterns, meteorological conditions, time lapse since last measurable precipitation, degree and extent of imperviousness, hydrologic and hydraulic characteristics, rainfall-runoff relationships, street sweeping and other public works activity, and land use. The measurements and other data collection would need to be continued over a sufficiently long time span to permit verification of the relationships developed between the correlated study data and the field measurements of pollutant discharges and the quality of receiving waters. Coeffecients of variation and confidence levels could then be determined and methods could be developed for making estimates of water quality for specified values of the manipulatable parameters selected.

After the field studies and analyses, last described, progress to a satisfactory point, it should be possible to make reasonably valid estimates of in-stream water quality by predictive methods through the use of mathematical modeling. Although the state-of-the-art of modeling water quality and hydrology makes its use practical, the lack of sufficient and reliable field data leaves much work to be done to make its "application" to urban areas for water quality prediction a useful and reliable tool. However, when this is accomplished, a powerful tool will be available to predict in-stream water quality and to project the "effects" of changing land use, public works practices, urban growth, changes in the urban environment, and other parameters.

POLLUTANT LOADINGS

The study of the relationships between in-stream water quality and pollutant discharges, is facilitated by developing graphs of mass emissions of pollutants entering the stream from both point and non-point sources, as a function of time. The vertical scale is usually expressed in pounds of pollutant per day, or equivalent units and the horizontal scale is time in hours or other time units. The development of these graphs (usually termed "mass emission pollutographs") may be accomplished using data from field measurements of many real-world events. It is also possible to develop pollutographs by modeling and to determine their sensitivity to changes in various natural and urban parameters; however, this approach is practical only in those few places where sufficient, good field data is available for developing and testing computer programs and verifying results of predictions.

A pollutograph is developed from field data by multiplying the pollutant concentration at a given time and observation point by the value of the flow past the point at that same time. This product is the time-rate at which the specific pollutant under study is being discharged past the sampling-gaging station. When multiplied by an appropriate conversion factor, it is the "pollutant loading" in the discharge stream--at the moment when the flow was gaged and the sample taken. By plotting "pollutant loading versus time of observation", a curve can be developed to represent variation in the pollutant loading with time. This curve is the graphical representation previously referred to as a "mass emission pollutograph".

The dotted curves in Figure 1 are examples of mass emission pollutographs developed from field data taken in a storm sewer serving a small urban watershed. These curves show the time variations in pollutant loading--the upper graph representing biochemical oxygen demand (BOD), and the center graph representing suspended solids. The pollutant loading are expressed in pounds of pollutant per day.

A hydrograph showing the variation of flow with time for the study point is given by the solid curve at the bottom of the figure. Pollutant concentrations for BOD and suspended solids are also shown as solid lines. Inspection of these curves reveals that the peak flow rate was quite low; but, because of the fairly high concentrations of both BOD and suspended solids associated with this flow rate, the pollutant loadings were relatively high. During the initial period of runoff, pollutant concentrations and runoff were increasing at rapid rates until a peak was reached after about 15 minutes. This gives evidence of

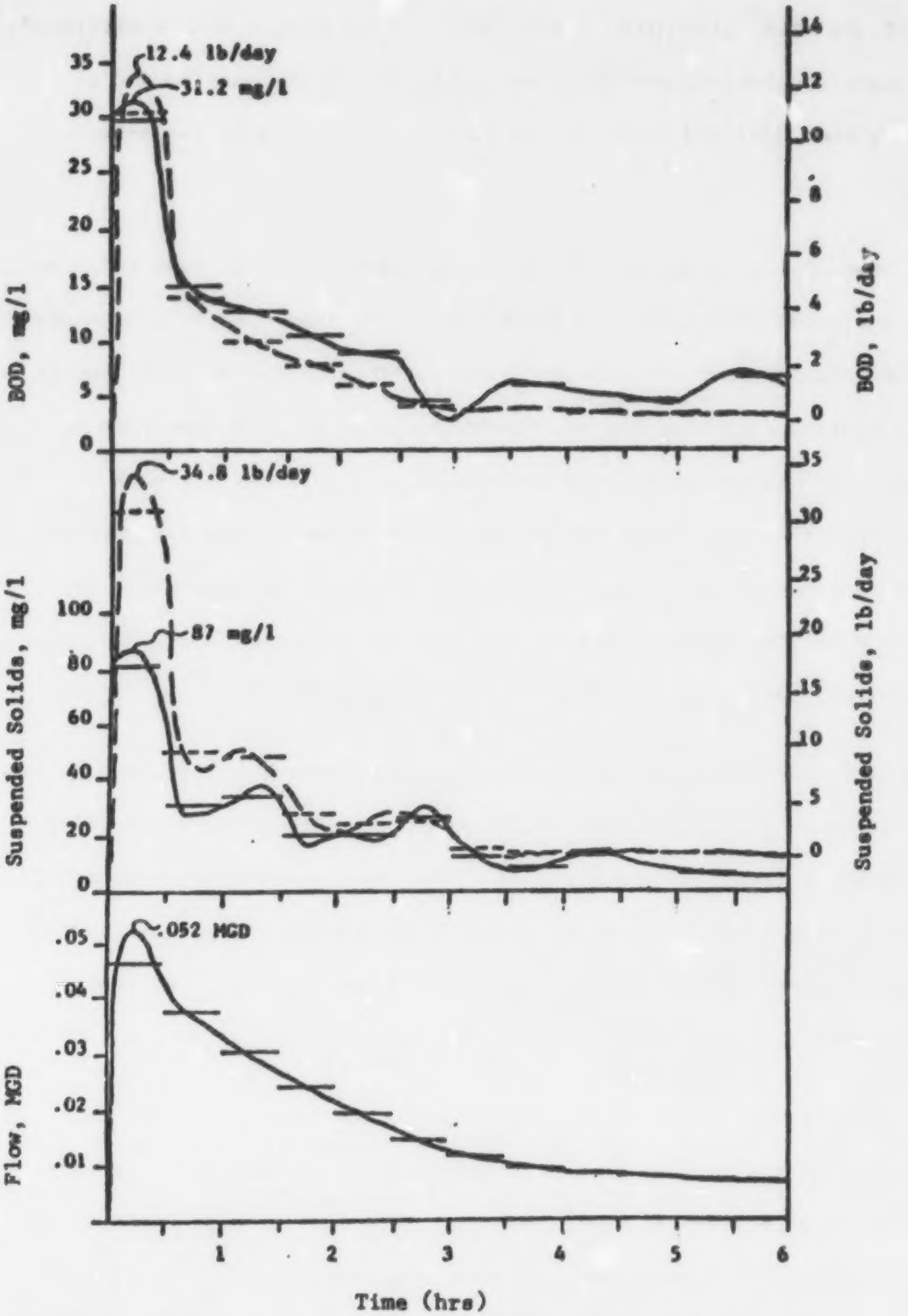


FIGURE 1. Variation in Flow, BOD, and Suspended Solids During the Storm of Oct. 27, 1972 at the Urban Sampling Station.

Source: Stormwater Runoff Quality for Urban and Semi-urban/Rural Watersheds, by F. T. R. Mc Elroy III and J. M. Bell, February 1974, Purdue University Water Resources Research Center the ocurrence of the often discussed "first flush" of pollutants from a watershed. As the runoff event progressed, the flow rate diminished rather uniformly, although there were some dips and rises in the concentrations and in suspended solids loadings.

For either of the curves in the foregoing illustration of mass emission pollutographs, the total pollutant discharged during the runoff event can be obtained by summing the incremental pollutant contributions over the entire runoff event. This is done by computing the area beneath the curve from time zero to the cut-off time. The values would be expressed in pounds of BOD for each of the upper set of curves--and, similarly, pounds of suspended solids for each of the lower curves. Although the total mass of pollutants can be determined as stated above, of much more significance in water quality studies is the mass of pollutants discharged during periods of peak pollutant loading.

In summary, the pollutant loading of a given discharge can be thought of as being the arithmetic product of the "pollutant concentration" at a specified time and the discharge flow rate at that time. The basic problem of determining pollutant loadings from field data is one of sampling and gaging the discharges at selected time intervals to determine concurrent values for pollutant concentration and flow rate.

The evaluation and study of the "loadings" of various pollutants in stormwater flows gives one a grasp on understanding water quality characteristics and the significance of stormwater contributions. It should be kept in mind, in light of the foregoing discussion, that the in-stream impacts of stormwater runoff is a function of both the quantity of flow and the pollutant concentration. In a given runoff event, either one of these variables, or both, may be the major cause of a quality problem in the receiving waters.

URBAN WATERSHED vs. SEMI-URBAN/RURAL WATERSHED

In 1972, Mc Elroy and Bell of the Purdue University Department Environmental Engineering conducted a field study of stormwater runoff from a small urban watershed and a larger semi-urban/rural watershed, located nearby. In addition to studying sampling procedures, the objectives were to characterize and quantify the pollution in stormwater runoff, compare the runoff from the two watersheds, examine effects of first flushing, and measure the effects of varying sampling frequency on the mass emission pollutographs.(1)

The purposes of including a summary of the conduct and results of this study in this paper are (1) to illustrate the field procedures that can be used to characterize stormwater pollution, (2) to show some examples of pollutant loading as a function of time, (3) to compare the pollutant loadings of the stormwater runoff from the two watersheds to illustrate the effects of different land uses; and (4) to illustrate how pollutant concentration and runoff flow rates influence the magnitude of pollutant loadings.

At the urban watershed, flow gaging and sampling of runoff discharges were conducted at a gaging-sampling station located in a concrete pit receiving runoff from a storm sewer serving the 29-acre watershed. The watershed is a fully-developed residential area having 38% impervious area and containing 72 single-family dwellings with a total population of 252 persons (8.7 persons/acre). The semi-urban/rural watershed has an area of 292 acres. It includes partially-developed residential land and farm land--178 acres and 114 acres, respectively. The watershed is located about 4 miles from the urban watershed. The population of 1,000 persons results in an average population density of 3.4 persons per acre. The gaging-sampling station consists of two Parshall flumes in a drainage ditch and an instrument shelter located underground, nearby. For analyses of the quality of runoff, semi-continuous composite samples of 1000 ml volume were taken at half-hour intervals at both sampling stations during 4 rainstorms.

The researchers identified BOD and suspended solids along with total coliforms as the parameters most used for determining the quality of stormwater runoff. The dotted curve at the top of Figure 2 shows the BOD mass emission pollutographs for the semi-urban/rural watershed for a rainstorm of November 13, 1972. The units are pounds-per-day plotted against time from start of runoff. The suspended solids mass emission pollutograph is shown as a dotted line in the center of the figure. Similarly, the dotted curves in Figure 3 are the pollutographs for BOD and suspended solids for the urban watershed during the same rainstorm. "Concentrations", both for BOD and suspended solids are shown as solid lines. Inspection of the curves reveal consistently higher values for the pollutant concentrations at the urban site.

An analysis of the pollutographs for the semi-urban/rural site was made followed by a comparison of quality of runoff from the two test watersheds. In order to compare the two watersheds, it was necessary to derive a useful factor which could reduce the pollutant values to a common scale. This was done by considering the effect of size of the watershed and rate of runoff on the peak pounds per day of pollutants produced. The use of the units of pounds of pollutants per day per acre reduces the pollutants to an equal basis with regard to size of the watershed. By next considering the effect of flow on the poundage or by dividing the pounds per acre per day by MGD one has, in effect, reduced the values to concentration of pollutants generated by storm flow per acre of watershed. The data shows that the concentration of pollutants resulting from the runoff from one acre of urban watershed is much greater than that from the semi-urban/rural watershed. The ranges of the peak concentrations are shown in Table 1. Both minimum and maximum peak values are much higher for the urban watershed as compared to those determined for the semi-urban/rural watershed for all parameters studied--BOD, SS, Total Coliforms and Fecal Coliforms.

TABLE 1. COMPARISONS OF PEAK POLLUTANT CONCENTRATIONS IN STORMWATER RUNOFF FROM AN URBAN WATERSHED AND A SEMI-URBAN/RURAL WATERSHED

Parameter Measured	Range of Peak Pollutant Concentrations	
	Semi-urban/Rural Watershed	Urban Watershed
BOD (mg/1)	3 to 7	11 to 44
Suspended Solids (mg/1)	6 to 170	62 to 250
Total Coliform Counts (organisms/ml)	930 to 46,000	930 to 240,000
Fecal Coliform (organisms/ml)	930 to 9,300	430 to 93,000

Source: Derived from data published in Stormwater Runoff Quality for Urban and Semi-urban/Rural Watersheds, by F. T. R. Mc Elroy III and J. M. Bell, February 1974, Purdue University Water Resources Center, West Lafayette, Indiana

A "first flush" of suspended solids and BOD was exhibited at the urban sampling station; however, no first flush of BOD was apparent at the semi-urban/rural station and only a very small first flush of suspended solids was observed. The authors also pointed out that although "first flush" was evident, several subsequent flushes of suspended solids occurred after the initial flush when the flow increased dramatically. However, upon reaching maximum flow, solids concentration decreased and remained constant regardless of the flow pattern. This implies that minimum flow is required to completely flush the solids from the basin. The magnitude of this flow is dependent on the characteristics of the watershed and other parameters such as intensity of rainfall, duration of rainfall, antecedent dry period, etc.

Another conclusion from the study was that the mass emission pollutographs of BOD and suspended solids were affected by both concentration and flow. The concentration affected the shape of the pollutograph while the flow affected both the shape and magnitude of the pollutograph. The flow hydrograph had a much more dramatic effect on the shape and magnitude of the pollutograph than did concentration.

Inspection of the hydrographs and the pollutographs in Figure 2 and Figure 3, reveals that the mass emission of pollutants is greater for the greater runoff rates. For smaller runoff rates the flows pick up less pollutants and the mass emission of pollutants into the receiving waters is less. Under the latter circumstances, there is less impact on "assimilative capacity" of the receiving waters.

SOURCES of URBAN STORMWATER POLLUTANTS

The many point sources and non-point sources contributing to the pollution of urban stormwater runoff are difficult to list and classify in a comprehensive manner. Also, new sources emerge as the wheels of progress turn. Some of the more readily and significant sources are listed below:

demolition and construction operations
land grading and excavation
products of erosion from wind and water
material stockpiles
salt application to streets, roads and other paved areas for snow and ice control
debris from littering and vehicle movements (droppings from trucks, rubber and asbestos from vehicles, etc.)
particulates from stacks of heating equipment and industry
fertilizer, pesticide and other chemical applications
leaves, grass clippings and trimmings from other vegetation
petroleum spillage and leakage
disposal of waste materials in storm sewers (oil, cleaning liquids, chemicals, animal wastes, etc.)
dumping of refuse in streets and roadside ditches
innundation of wastewater treatment facilities by flood waters
sewer catch basins

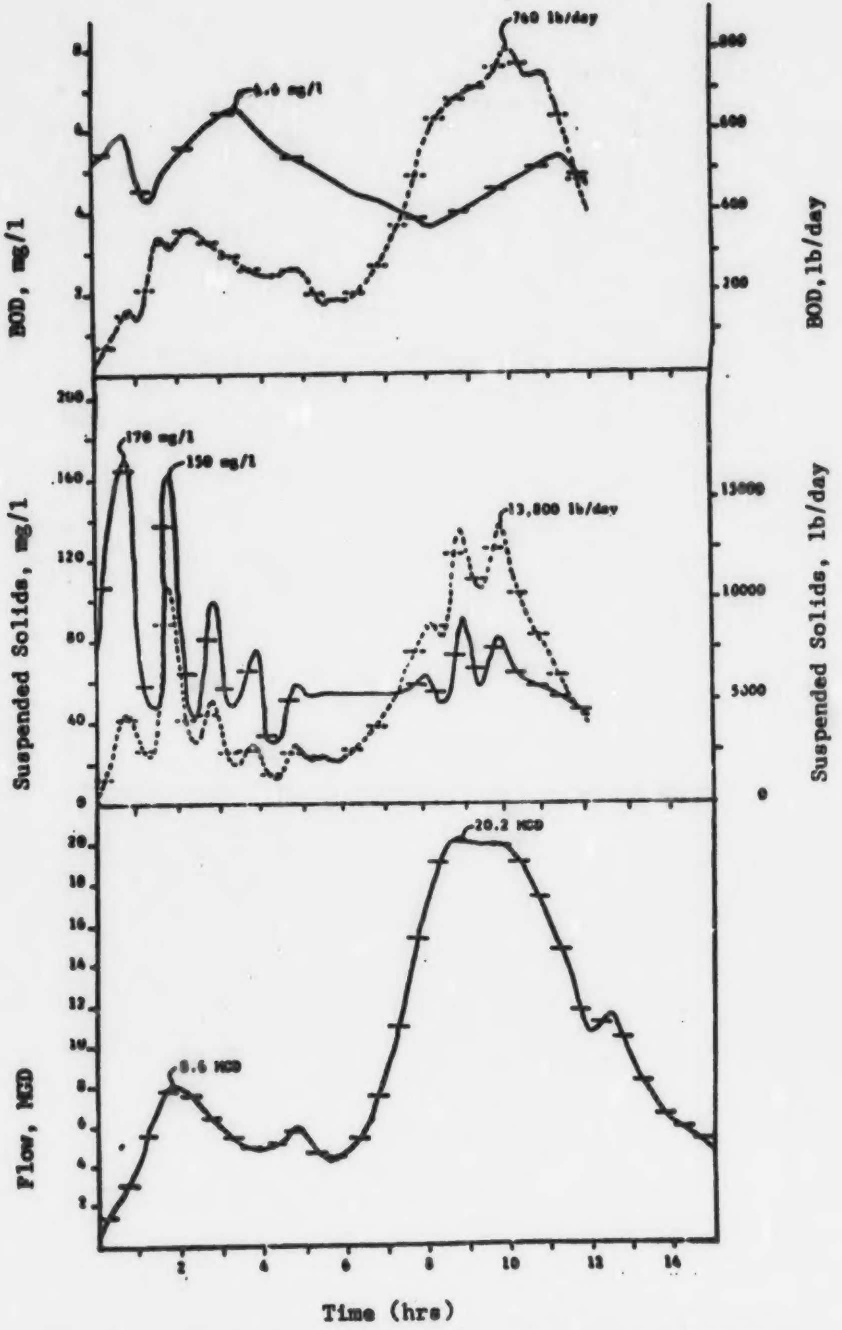


FIGURE 2. Variation in Flow, BOD, and Suspended Solids for the Storm of Nov. 13, 1972 at the Semi-Urban/Rural Sampling Station.

Source. Stormwater Runoff Quality for Urban and Semi-urban/Rural Watersheds, by F. T. R. Mc Elroy III and J. M. Bell, February 1974, Purdue University Water Resources Research Center

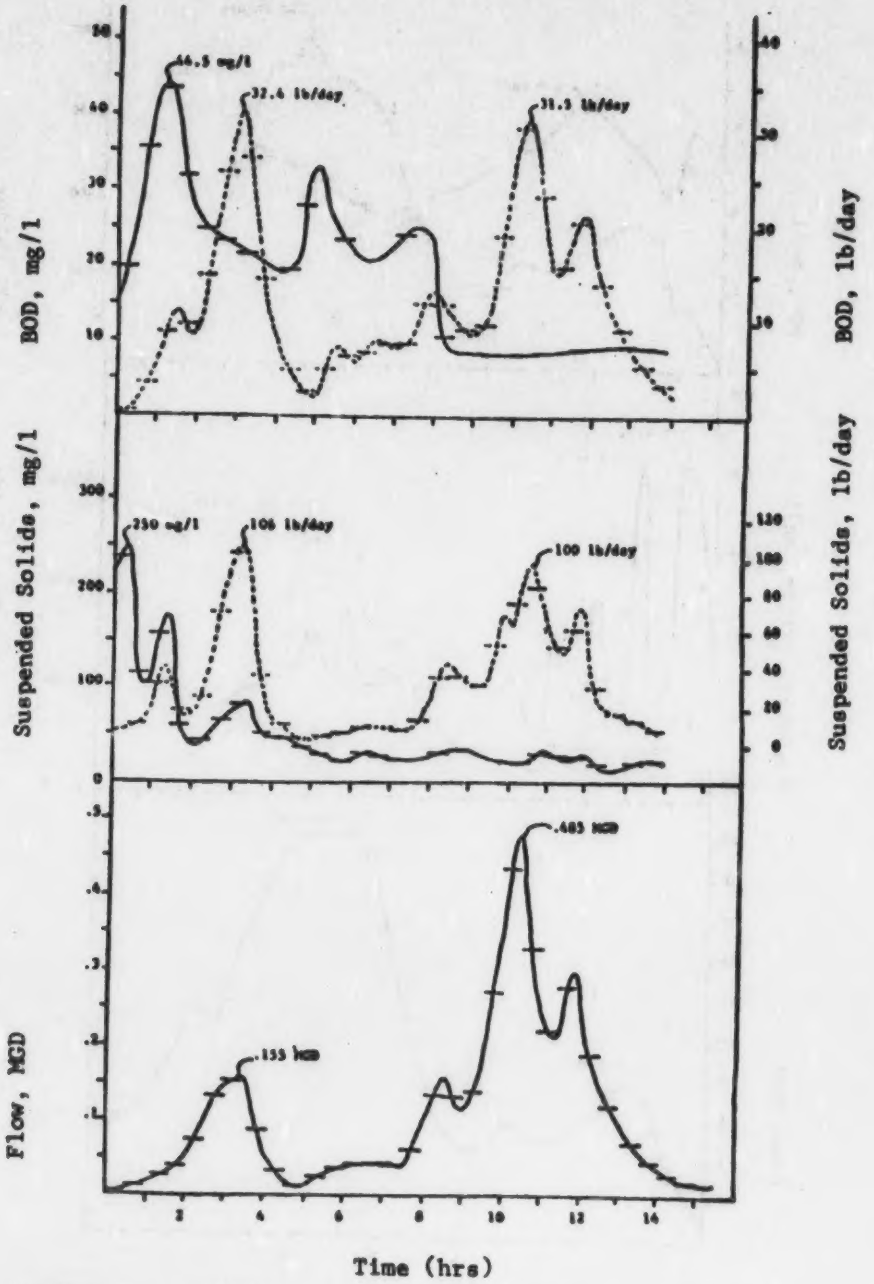


FIGURE 3. Variation of Flow, BOD, and Suspended Solids During the Storm of Nov. 13, 1972 at the Urban Sampling Station.

Source: Stormwater Runoff Quality for Urban and Semi-urban/Rural Watersheds, by F. T. R. Mc Elroy and J. M. Bell, February 1974, Purdue University Water Resources Research Center

overflows and backups of sanitary sewers
overflows of stagnant ponds and waste disposal lagoons
sewer discharges of washwaters from scrubbers of air pollution control equip.
leachates from sanitary landfills
surface discharges from septic tank leaching fields
cross connections from sanitary sewers, either accidental or illicit

Some of the above sources may also act to pollute groundwater and water supplies in natural aquifers, wells and reservoirs. Among other potential sources of underground water pollution are activities of public agencies and private organizations designed to solve specific problems: e.g., land application methods for wastewater treatment, stormwater injection, disposal of irrigation return water having high mineral content, brine disposal, etc.

Pollutants in sediments produced by runoff may cause the largest single impact from urban stormwater runoff on water quality. The amount, or "yield", of sediment varies with land use and site characteristics. It may originate from runoff flows over rural land, farmland or urbanized areas. High yields of sediment are produced in connection with land grading, excavation and demolition, and construction activities. The pollutional constituents in sediment generally can be classified as non-organic solids, organic materials, trace metals, soil salts, and chemicals of various types including fertilizers, pesticides and others.

Sites that have been denuded are often allowed to remain idle pending land development and this produces erosion and sediment yields. Runoff from streets, parking lots and other paved surfaces in urban areas is another major source of sediment yield and pollutants in receiving waters.

Much of the material transported by runoff does not become sediment in but remains in suspension in the initial receiving waters. These "suspended solids" constitute another major impact on the water quality of receiving waters.

Substances that become dissolved in stormwater also cause an impact on water quality as they are assimilated and diluted by the receiving waters.

RELATIVE EFFECTS OF STREETS AND THEIR USE

This section highlights some of the findings of various studies concerning the degree to which urban right-of-ways for automotive transportation contribute to the pollution of stormwater. Some of this information was obtained from a paper given by Martin J. Manning in 1975 at the University of Florida. (2)

Streets, alleys and roads constitute one of the major contributors to stormwater pollution in urban areas. The deposition on these surfaces of contaminants from the operation of vehicles, the accumulation of litter and trash, eroded materials from streets surfaces and nearby paved and unpaved areas, settling of air borne particulates, application of salts for snow and ice control, and other activities, combine to make "street accumulations" a contributor to 50% or more of the pollutant loadings in some urban stormwater runoff. Researchers have found that for high runoff rates over streets, the pollutant "mass emissions" are about what would be expected based upon measured street accumulations. But for low runoff rates over streets and paved surfaces, measurements have shown less pollutant mass emissions than what is usually expected from theoretical analyses. The reason for this "attenuation", apparently, is not fully explainable.

Snow and ice readily "accumulate" significant amounts of the pollutants generated in urban areas. A 1973 report of a Canadian study(3) conducted for the National Capitol Area reported significant concentrations of various pollutants in samples of snow taken in the urban area of Ottawa-Carleton. Also, the need for and practice of controlling ice and snow in urban areas adds another dimension to the pollutant sources--namely, "purposeful" application of a pollutant to street and road surfaces. Sodium chloride (common salt) is the most-widely used chemical for ice and snow control, except at airports where less corrosive materials are used. Salt application rates up to 700 pounds per lane-mile of road were reported in Toronto. Results of the study included an estimate that approximately 84% of the deicing salts used in the Ottawa-Carleton area ran off as brine after application. Between 6 to 10% of the salt found its way into receiving waters by runoff from melting of snow and ice that had been piled-up or hauled away during mechanized snow and ice removal operations.

The type of pavement surface is a factor that contributes to the "litter accumulations" on streets because of "surface-wear" and effects of weather. It has been reported that about 25% of the total litter accumulation on street pavements may be derived from the pavement materials. Also,total accumulations of litter, dust and dirt have been found to be much heavier on asphalt streets than on concrete streets.

CONCLUSIONS

Unfortunately, the majority of existing stormwater runoff quality information reported is given as "mean" pollutant concentration or "averages" of samples taken from one or more runoff events. These values are usually given without regard to their relationships to rainfall, runoff and time variations of other parameters. This diminishes the usefulness of the field data.

However, on the basis of data of this type, "average" urban stormwater runoff quality may be characterized as having solids concentrations equal to or greater than raw sewage, BOD concentrations approximately equal to that of effluents from secondary sewage treatment, and bacterial contamination from 2 to 4 orders of magnitude less than untreated sewage.

The state-of-the-art in assessment of pollution of stormwater runoff as a function of land use and urban development is in a preliminary state of development. Because of this and the lack of conclusive findings by researchers, it seems inappropriate to review here the findings of various studies as they relate to the relative effects of different land uses. However, several field studies in which the effects of land use were investigated are included in the list of references.

REFERENCES

1. Stormwater Runoff Quality for Urban and Semi-Urban/Rural Watersheds, by Felix T. McElroy III and John M. Bell, Purdue University Water Resources Research Center, West Lafayette, Indiana, February 1974, 156 p

2. Urban Stormwater Pollutant Loadings, M. J. Manning, Second Annual National Conference on Environmental Engineering Research, Development and Design, University of Florida, Gainesville, July 20-23, 1975, 18 p

3. Snow Disposal Study for the National Capitol Area, by J. L. Richards & Associates Limited and Labrecque, Vezina & Associates, Ottawa, Ontario, Canada, June 1973, 143 p

OTHER PERTINENT PUBLICATIONS

4. Contributions of Urban Roadway Usage to Water Pollution, by Donald G. Shaheen, Biospherics, Inc., for the U.S. Environmental Protection Agency, EPA-600/2-75-004, March 1975, 346 p

5. Urban Stormwater Management and Technology, An Assessment, by John A. Lager and William G. Smith, Metcalf & Eddy, Inc., Palo Alto, California, for the U.S. Environmental Protection Agency, EPA-670/2-74-040, December 1974, 447 p

6. Characterization and Treatment of Urban Land Runoff, by Newton V. Colston, Jr., North Carolina State University, Dept. of Civil Engineering, Raleigh, for the U.S. Environmental Protection Agency, EPA-670/2-74-096, December 1974, 117 p

7. Water Quality Management Planning for Urban Runoff, URS Research Company, San Mateo, California, for the U.S. Environmental Protection Agency, Contract 68-01-1846, December 1974.

8. A Study of the National Scope of Urban Pesticide Runoff, by CONSAD Research Corporation, Pittsburgh, PA, for the U.S. Environmental Protection Agency, Contract 68-01-2225, 1975

9. Toxic Material Analysis of Street Surface Contaminants, by Robert E. Pitt and Gary Amy, USR Research Company, for the U.S. Environmental Protection Agency, EPA-R2-73-283, August 1973, 119 p

10. Pollution Attributable to Surface Runoff and Overflows from Combined Sewerage Systems, by D. H. Waller, Atlantic Industrial Research Institute, for Central Mortgage and Housing Corporation, Ottawa, Ontario, Canada, April 1971, 160 p

11. A Milti-Phasic Component Study to Predict Storm Water Pollution from Urban Areas, by AVCO Economic Systems Corporation, for the Office of Water Resources Research, U.S. Dept. of the Interior, Contract 14-31-0001-3164, December 1970, 187 p

12. Storm Water Pollution from Urban Land Activity, by AVCO Economic Systems Corporation, for the Federal Water Quality Administration, Contract 14-12-187, July 1970, 163 p

13. Water Pollution Aspects of Urban Runoff, by the American Public Works Association, for the Federal Water Pollution Control Administration, Contract WA 66-23, January 1969, 272 p

INSTREAM IMPACTS OF URBAN RUNOFF

E. D. Driscoll - Hydroscience

MAJOR WATER QUALITY PROBLEMS IN URBAN AREAS

The nature of water quality problems associated with the receiving waters in and around metropolitan areas is quite varied. Although a list of common potential problems can be drawn up readily, local factors have a predominant influence in determining both the class of problem, its severity, and the specific source or sources which are most critical. The local factors which affect water quality include climate, geography, population, population concentration, the nature and degree of industrialization in the area, the receiving water system, its nature, size and hydrology; and the nature of the surrounding area - both upstream and downstream of the urban area itself.

Water quality problems, either real or potential, will be generated by waste loads which enter the receiving water from the area in question. There are a number of different types of sources which contribute waste loads, and these are generally classified as either point sources or non-point (distributed) waste loads. They include discharges of domestic sewage, either treated or untreated, industrial waste discharges, storm runoff from urban, agricultural, or undeveloped land areas, surface returns from irrigated agriculture, and sub-surface seepage of either groundwater or percolating agricultural irrigation water. Classification of these sources into point or distributed sources is somewhat ambiguous in certain cases. Storm runoff, for example, is essentially a non-point source in that it is generated by precipitation falling over a wide area. It would be considered viewed from the perspective of its impact on water quality in the receiving water which ultimately receives its runoff, it can be evaluated either as a distributed source (as in upstream areas), or as a point source. An example of the latter would be an urban area where surface runoff from storms are collected and finally enter the stream at a single point which can be readily intercepted or treated. It is important in developing an approach to the solution of water quality problems, that classifications (point vs. non-point), while useful in general discussions, should not be adopted blindly, but should be adapted to fit the simplest and most effective approach.

Each of the individual sources has distinctive general characteristics. The type of pollutant or pollutants which predominate can differ radically between sources, as can the absolute quantity contributed. Further, the type of control which may be applied, such as partial containment or treatment will usually modify both the total quantity of pollutant in the source, and the predominant type present. The method of analyzing the effect of all sources on water quality, and the impact of alternative control measures must be able to handle these variations effectively.

Types of water quality problems which can result from waste loadings which exceed the capability of the receiving water to assimilate include the following (See Tables I and II).

- Aesthetic deterioration - Either general appearance (dirty, turbid, cloudy) or the actual presence of specific, objectionable conditions (odors, floating debris, oil films, scum or slimes, etc.) may make the receiving water unattractive or repugnant to those in its proximity.

- Dissolved Oxygen Depletion - Organic materials stimulate the growth of bacteria which may consume oxygen faster than natural processes can replenish. This condition may or may not be visually apparent. In the extreme, discoloration, gas formation and odors may be apparent - however well before this extreme is reached, conditions suitable for a balanced aquatic population of fish and lower species in the food chain may be violated. The presence of unoxidized nitrogen compounds (e.g. ammonia) is in some cases a significant element in water quality problems related to low dissolved oxygen levels.

- Bacteria/Virus Concentrations - The presence of excessive concentrations of objectionable microorganisms can impair the ability to utilize the receiving water for certain water supply and recreational purposes.

TABLE I

CLASSES OF INSTREAM IMPACTS

AESTHETIC

DISSOLVED OXYGEN DEPLETION

SEDIMENTS AND DEPOSITS

EXCESSIVE AQUATIC GROWTH

PUBLIC HEALTH THREATS

IMPAIRED RECREATION VALUE

ECOLOGICAL DAMAGE

REDUCED COMMERCIAL VALUE

TABLE II

CONTAMINANTS IN URBAN RUNOFF

FLOATABLES AND VISUAL CONTAMINANTS

DEGRADABLE ORGANICS

SUSPENDED SOLIDS

NUTRIENTS

BACTERIA, VIRUS

TOXIC MATERIALS

DISSOLVED SOLIDS

- **Suspended Solids - Particulate matter may contribute to a variety of problems, such as objectionable aesthetic consideration, formation of sediment deposits which smother bottom dwelling aquatic organisms, impeded navigation or restrict river flows contributing to flooding potential.**

- **Nutrients - The discharge of materials which fertilize or stimulate excessive or undesirable forms of aquatic growth can create significant problems in some receiving water systems. Overstimulation of aquatic weeds or algae (eutrophication) can be aesthetically objectionable, cause dissolved oxygen problems, and in extreme cases can interfere with recreational use of impededing small boat navigation, creating odors, and heavy mats of floating material at shorelines.**

- Dissolved Solids - A number of beneficial uses can be impaired by excessive concentrations of dissolved solids. Both domestic and industrial water uses are sensitive to dissolved solids concentrations. Irrigated agricultural is quite sensitive to the salt content of the applied water. On a practical day to day basis, farmers must compensate for high salinity in irrigation water by increased quantities of irrigation water. This imposes additional demands on water development and conveyance programs, and further contributes to drainage problems. Effective agriculture can be destroyed if irrigation rates required to compensate for high salinity exceed the percolation and drainage capacity of the soil.

- **Toxicity - Toxicity problems can fall into either of two categories: Metals/Pesticides/Persistent Organics - may exhibit a subtle, long term effect on the environment in areas well removed from the area under consideration, by the discharge of small quantities which gradually accumulate in sensitive areas.**

  Ammonia, and byproducts of effluent chlorination, under some conditions can exhibit a local, more immediate impact.

It will be useful to examine very briefly some examples of water quality problems associated with metropolitan areas which we have analyzed. They are presented to illustrate the wide variety of situations which are encountered, and to indicate that no single solution or solution approach is at all appropriate.

- Boston Harbor - One of the more important water quality problems in this area was closure of beaches at rather frequent intervals because of excessive coliform counts. Although many sources of wastes entered the system, it was predominantly combined sewer overflows which.created the objectionable condition. Other constituents in the storm runoff were not particularly significant. Analysis in this case focused specifically on coliform bacteria contributed by storm runoff. In the evaluation of alternative actions which included both reduction in amount and location of discharge points, the evaluation was made not on the amount of coliform discharged - but on the basis of the effect of each alternative considered on the number of days in which objectionable counts would occur. Management decisions were made by comparing the cost of each alternative to the number of days beaches would require closing under that alternative.

- Potomac River at Washington, D.C. - In this case, both municipal and industrial discharges and urban storm overflows were important. Significant pollutants were bacteria and virus, TDS, and algal resulting from nutrient discharges. Growth projections for the area projected critical water supply limitations in dry years. Alternative approaches included additional reservoir construction upstream and withdrawal of supplementarv water supply from the upper reaches of the estuary. Because of tidal conditions and low fresh water outflow under conditions, flow reversals would occur with the result that downstream sewage discharges and ocean salts would, though diluted, be drawn back toward the water intake. Analysis in this case was directed toward projections of the effect of various alternatives on the quality of water as appropriate for processing by water supply and treatment facilities for Washington, D.C. Total dissolved solids, coliform, virus, and filter-clogging or taste and odor producing algae were the important elements, as they would occur at the point of water intake.

- Milwaukee, Wisconsin - This project evaluated the effect of retention basins in controlling storm overflow pollution loads, and evaluating their impact on quality in the Milwaukee River. In this case dissolved oxygen and suspended solids were the critical parameters, and were influenced almost totally by storm runoff - both from the intermediate urban area, and from upstream agricultural and suburban areas. Suspended solids caused objectionable deposits in the channel. Low dissolved oxygen levels were found to be due to direct organic discharges (BOD), the gross accumulations of putrescible sediments, and the diurnal variations in dissolved oxygen caused by nutrient stimulated algae growths in upstream areas.

PROBLEM DEFINITION

The foregoing illustrates several things. First, stormwater overflows can cause significant waste loads on receiving waters. Further the relative contribution of storm loads to total receiving water loads from urban areas increases dramatically as municipal treatment facilities achieve higher levels of removal efficiency. Figure 1 illustrates this factor schematically.

Secondly, at some point we must stop speaking of "the" stormwater problem - and focus on which of the possible problems we are concerned with. Each particular problem is caused by a different set of contaminants.

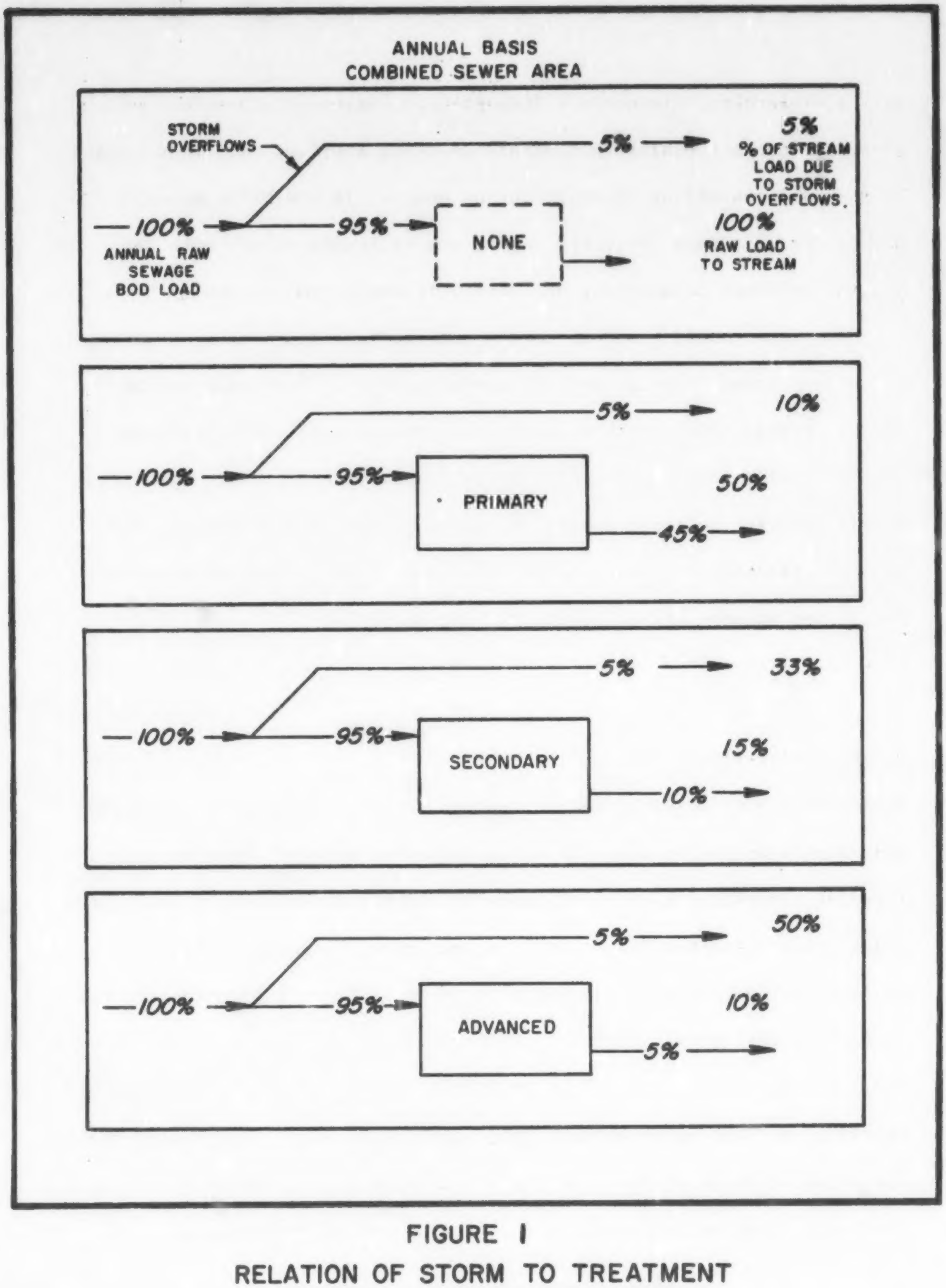

ANNUAL BASIS
COMBINED SEWER AREA
STORM OVERFLOWS
5%
5%
% OF STREAM LOAD DUE TO STORM OVERFLOWS.
100%
ANNUAL RAW SEWAGE BOD LOAD
95%
NONE
100%
RAW LOAD TO STREAM
5%
10%
100%
95%
PRIMARY
50%
45%
5%
33%
100%
95%
SECONDARY
15%
10%
5%
50%
100%
95%
ADVANCED
10%
5%

FIGURE I

RELATION OF STORM TO TREATMENT WASTE LOADS TO STREAMS

Different contaminants respond differently to control measures. An effective control program must concentrate on doing an appropriate job on the contaminants which are causing the problem - and not on those which have a negligible or insignificant effect. Therefore, an effective control program requires an accurate definition of the problem.

This isn't always easy to do, but it is important. For reasons which will become increasingly apparent during this seminar, it is impractical, if not physically and economically impossible, to control ALL stormwater overflows. We can't - as we do with municipal or industrial wastewaters - assign a minimum level of treatment to 100% of the waste load. We must be selective; we must be smart, to get the maximum "bang for our buck." It is entirely possible, because of the variable nature of the process generating these loads, that a control system arbitrarily selected might provide a less real benefit to receiving water quality, than an equal or even a less costly alternative. As an example, consider the hypothetical case illustrated by Figure 2. System A might be a retention tank; and System B, a smaller retention tank with filtration system, with greater removal efficiency at lower treatment rates. A treatment system on a storm overflow will experience a wide range of waste flows, and these flows may have a frequency distribution approximately as shown. Thus, alternate A, designed for a lower optimum rate than B, could in effect result in a greater degree of benefit to receiving water quality.

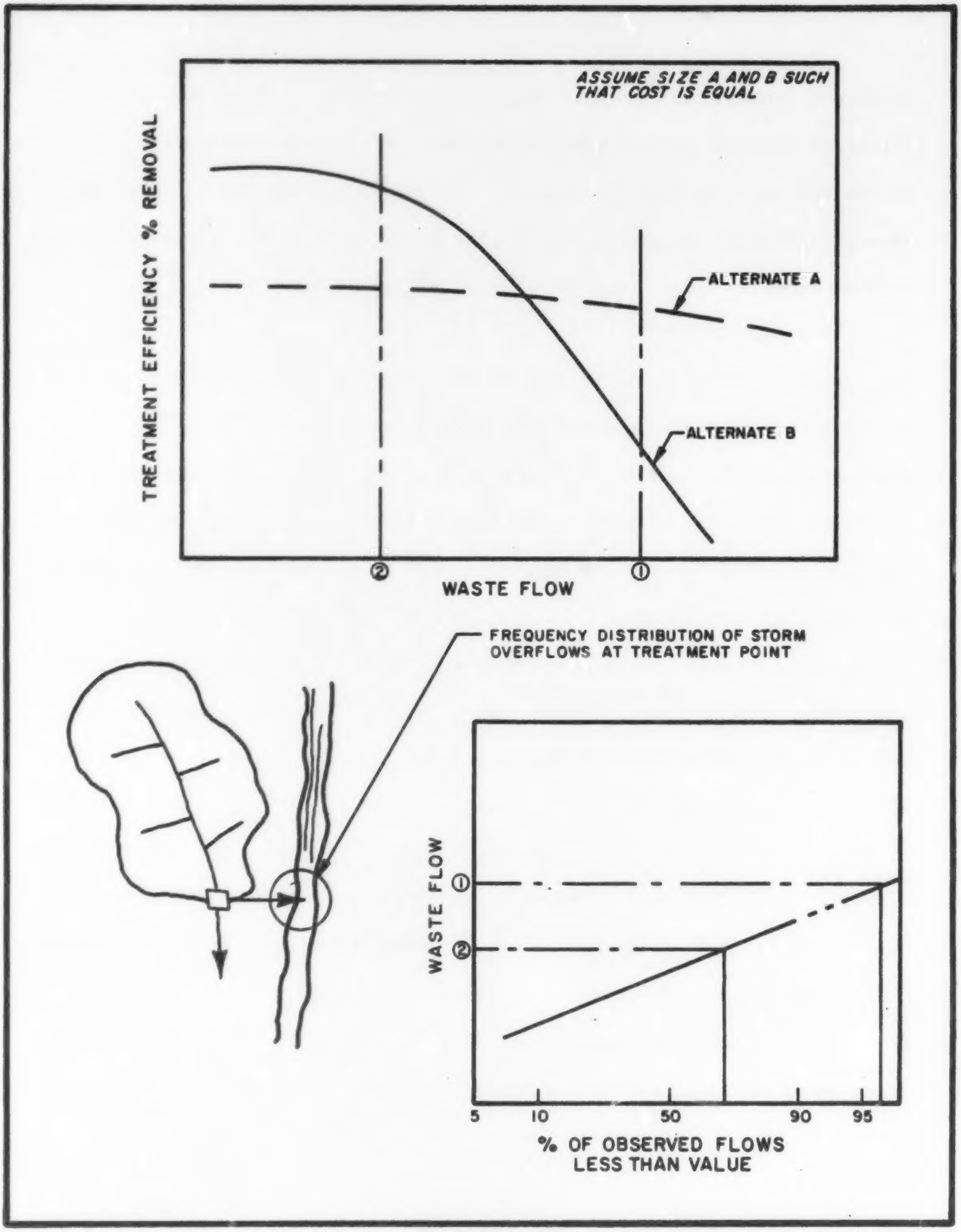

ASSUME SIZE A AND B SUCH THAT COST IS EQUAL
TREATMENT EFFICIENCY % REMOVAL
ALTERNATE A
ALTERNATE B
②
①
WASTE FLOW
FREQUENCY DISTRIBUTION OF STORM OVERFLOWS AT TREATMENT POINT
WASTE FLOW
①
②
5
10
50
90
95
% OF OBSERVED FLOWS LESS THAN VALUE

FIGURE 2
RELATIVE PERFORMANCE OF TREATMENT DEVICES FOR VARIOUS STORMWATER OVERFLOWS

How does one define a storm water problem. I submit that it should be defined - not in terms of how many pounds of contaminant X are discharged into the receiving water - but rather in terms of what changes in receiving water quality result from these loads, and how these changes (a) affect quality measures in relation to stream standards, and (b) how they impact beneficial uses. We should measure cost effectiveness not in terms of pounds removed - but in terms of preservation of beneficial uses.

Since the variability of the storm process makes it unlikely that any practical level of control will permit a receiving water quality objective to NEVER be violated, we must begin to think of assessing alternatives in terms of their influence on how frequently objectives will be violated.

If then, we should define a storm water problem in terms of its effect on the receiving water, what are the complexities involved in making such a determination. There are a number, and they relate to the basic nature of the problem, which might be summarized thus:

- Waste loads are flushed into receiving waters because of storms.

- The loads are transient; impacts are transient but may exert cumulative effects; i.e. effects may persist until the next transient load hits.

- The source of these loads (rainfall) is an extremely variable phenomenon. Predictability is possible only by invoking the concept of probability.

- It is difficult to measure the load in the sense that one would on a municipal sewage to design a treatment plant - because one, or a dozen or a hundred measurements won't tell (by themselves) what the "design waste load" should be.

- There is no way to tell - a priori - whether the critical receiving water condition results from the biggest 5 or 10 or 50 year storm, or from some sequence of run-of-the mill storms which occur every year or so.

SOLUTION APPROACHES

The complexities of the problem have been emphasized, not to suggest that it is a hopeless task, but rather to caution against naive or simplistic solutions. It may also help to understand the reasons why so many studies have been undertaken, largely under EPA sponsorship.

- Extremely variable phenomena require a lot of data to understand.

- We literally can't afford to apply arbitrarily high degrees of control indiscriminately.

- Storm generated pollution loads can be substantial, and contribute significantly to receiving water problems.

Effective approaches to the problems of storm water overflow, must therefore recognize the nature of the process generating the loads, and the nature of receiving waters where impacts are felt. The former is a topic covered by other discussions at this seminar. Let us now examine briefly the nature of receiving water systems and responses.

RECEIVING WATER SYSTEMS

Instream Impacts for any waste loading condition, will be influenced by the nature of the receiving water into which the load discharges. The "nature" of the receiving water is determined by the following elements.

- CLASSIFICATION
    - Fresh water streams and river
    - Tidal rivers and estuaries
    - Lakes and reservoirs
    - Harbors and oceans

- STRUCTURE
    - Dimensionality (1, 2, or 3 dimension)
    - Geomorphology (drainage area characteristics)
    - Hydrology
    - Meterology

- TRANSPORT PROCESSES
  - Advection - Transport predominated by translation
  - Dispersion - Transport predominated by mixing forces
  - Mixed - Both advection and dispersion are significant

- REACTION OF CONSTITUENTS
  - Conservative - e.g. TDS, Cl
  - Non-Conservative (Reactive)

    Rapid - (Hours - Days) - BOD, Bacteria

    Slow - (Months - Years) - Toxic Materials

A generalized characterization of receiving water systems is possible in a quantitative framework. Buried in the differential equations which are needed to adequately define system responses to loads, under transport and reaction conditions which prevail, is a very useful relationship.

$$\frac{KE}{U_2} = N$$

Where: K is the reaction rate of a particular contaminant

e.g. BOD decay K = 0.2 per day

Coliform K = 2.5 per day

E is the longitudinal dispersion due to mixing forces, which may include turbulence, velocity gradients, tidal effects, etc. It is expressed in terms of miles ^{2}/day

U is the advective flow, miles/day

Thus, in a strongly advective stream with little longitudinal mixing, N approaches 0 as a limit. In a strongly dispersive system where advective effects are insignificant in defining transport, N approaches infinity.

Experience permits us to bound this range more narrowly (see Figure 3). For values of N of 0.1 or less, advection may be considered to be the only significant transport element defining water quality responses to waste loads. For values of N of 10 or more dispersion controls water quality impacts. For intermediate values of N, i.e. on the order of 1, both mixing and advection significantly influence quality responses

The point here is that receiving waters can be characterized quantitatively, as well as the obvious qualitative characterizations. Further the characterization is of such nature that it will provide intelligence concerning how a contaminant will react. This permits judgements to be made concerning the load generation process (i.e. rainfall, runoff, treatment effects. etc.). Finally, these judgements can significantly influence our selection of the most effective approach to the problem - including monitoring programs to define the loads or selection and evaluation of control measures.

Before discussing the practical significance of these receiving water characteristizations, it is useful and instructive to recognize that the

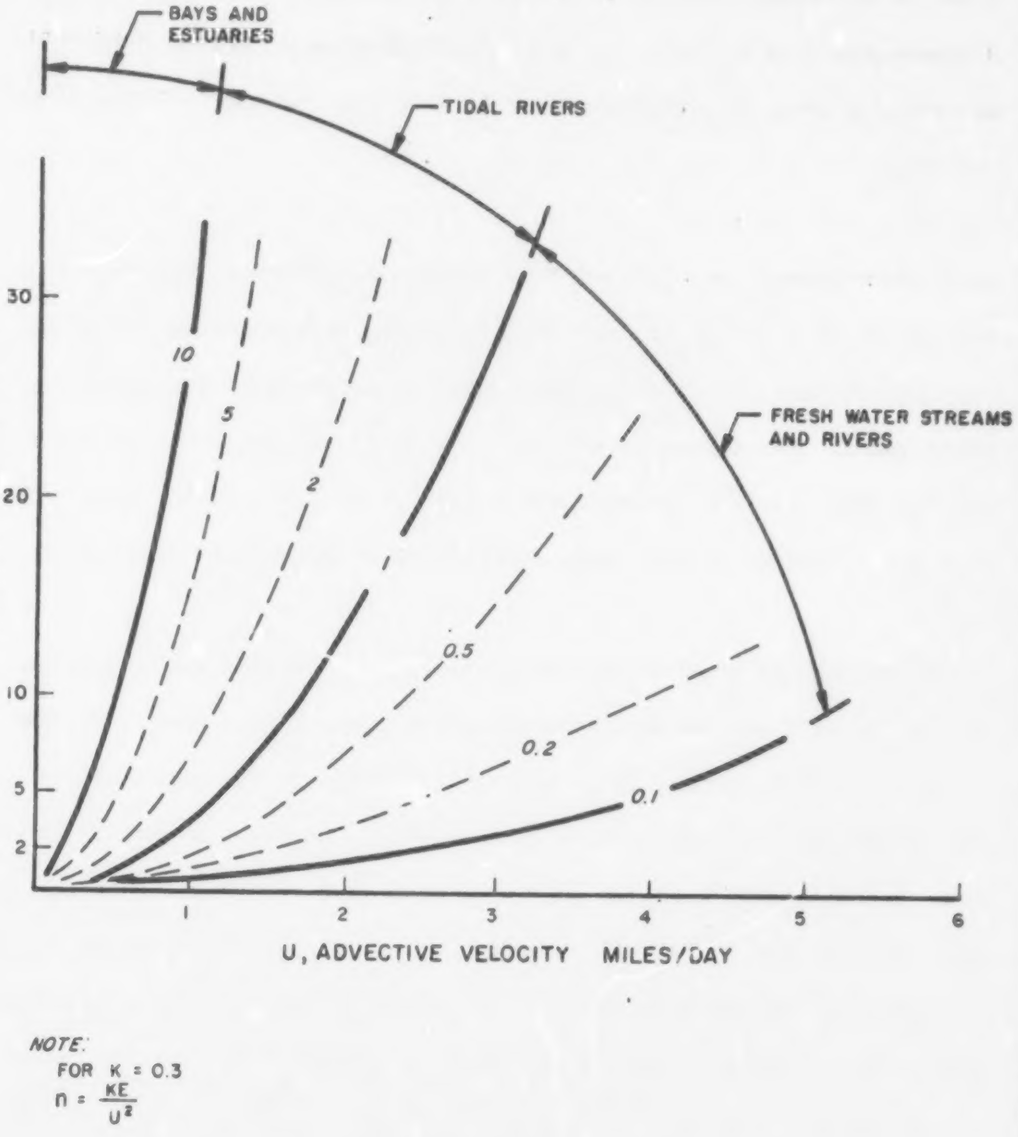


FIGURE 3

EFFECT OF ADVECTION AND DISPERSION ON RATIO $\frac{KE}{U^2}$

various classes of instream impacts can be associated with characteristic time and space scales. Figure 4 and 5 provide a generalized representation of the range of scales which storm overflows can influence. Together with receiving water characteristics, recognition of these scales can influence both the selection of appropriate methods for performing analyses, and selection of control processes.

SIGNIFICANCE - Some Examples

- From Time and Space Scales - LOADS (i.e. QxC) will probably never need to be defined for intervals of less than one hour. This interval may be required for some highly reactive contaminants (BOD, coliform, bacteria).

  For other contaminants - hourly variations in load - or even single storm averages may not be significant. Thus, TDS, or Metals, or in many cases Nutrients - long term (months, seasons, years) loadings are significant - not what happens in a single storm, or a particular moment during that storm.

  Important - because some analytical techniques are single event oriented. They may require excessive effort to provide the amount of information required in the appropriate time scale.

  Even for reactive constituents, the level of temporal detail in the distribution of loads entering the natural water, will be

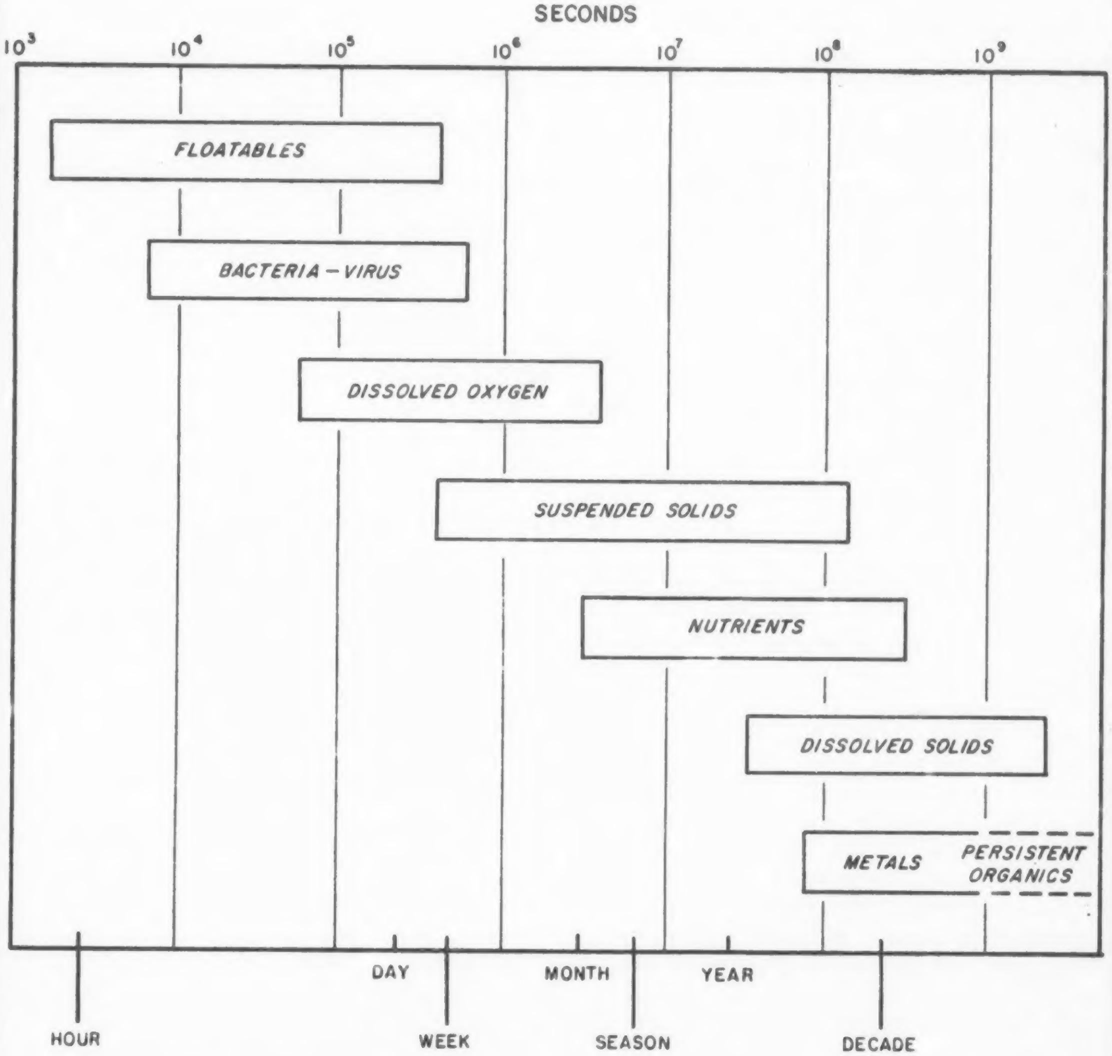


FIGURE 4
TIME SCALES
STORM OVERFLOW WATER QUALITY PROBLEMS

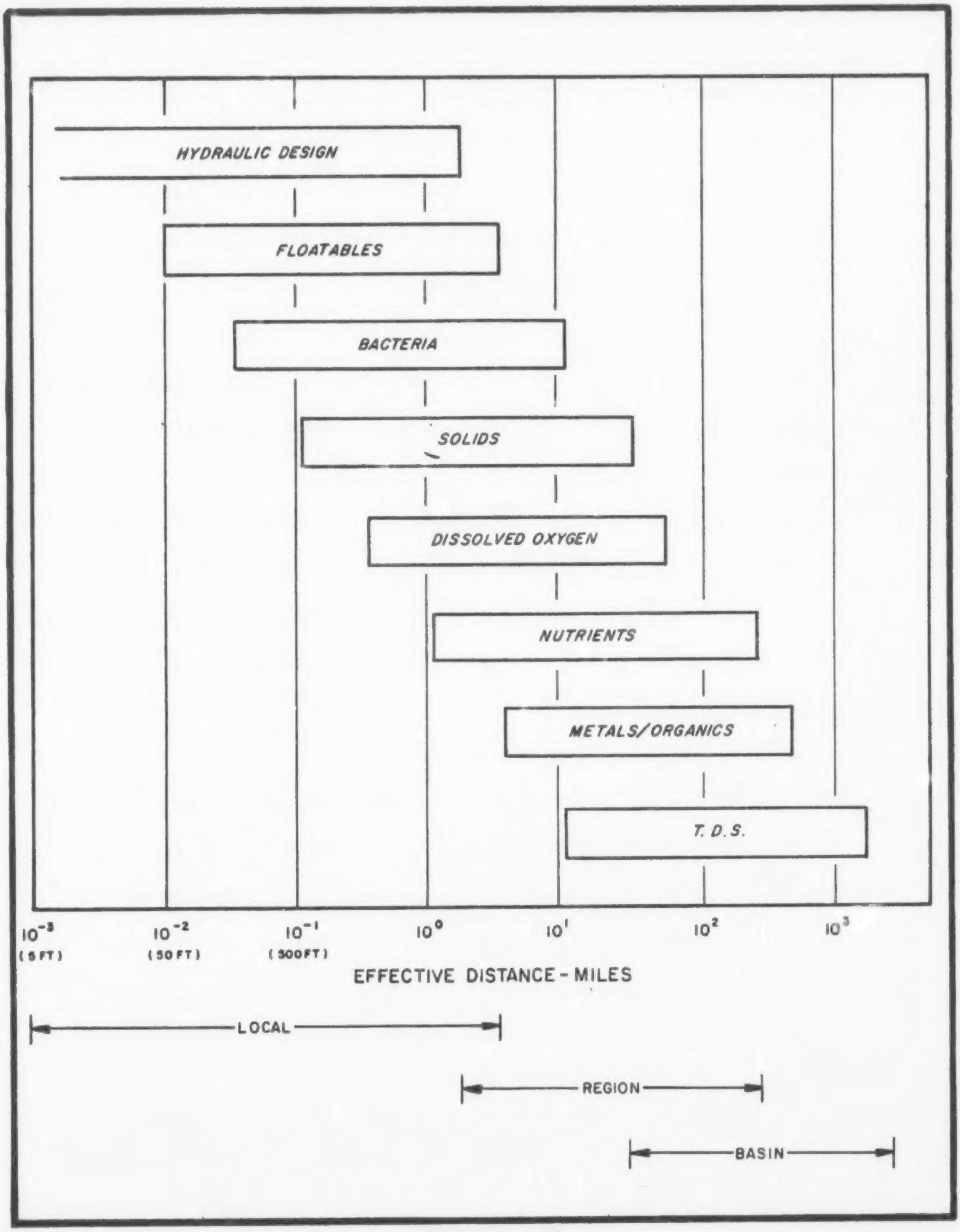


FIGURE 5
SPACE SCALES
STORM OVERFLOW WATER QUALITY PROBLEMS

influenced by the characteristics of the system. For example, waste loads entering a highly mixed system (tidal estuary) will be "averaged out" by the mixing forces in the receiving water - to the extent that a very fine definition of load variation (i.e. minutes or even hours) may be totally meaningless as far as instream impacts are concerned.

- This applies for advective and combination advective - dispersive systems as well - though the degree of "averaging" waste loads which is permissable will be increasingly restrictive as advection forces predominate. However - even with a purely advective system, there are practical limits to the level of detail which are significant. Figure 6 is a hypothetical case, with loads arbitrarily chosen, however a similar examination could be made for a particular condition. Note that averaging tends to over estimate slightly the (average) dissolved oxygen deficit generated by the indicated transient load. The averaging - on the other hand does not permit identification of the peak deficit. The question which must be asked now - is whether either beneficial use or stream standards are to be considered sensitive to the minimum dissolved oxygen which may occur during an interval as short as 1 hour (as per this example), versus whether our concern should be with minimum daily, weekly or monthly values.

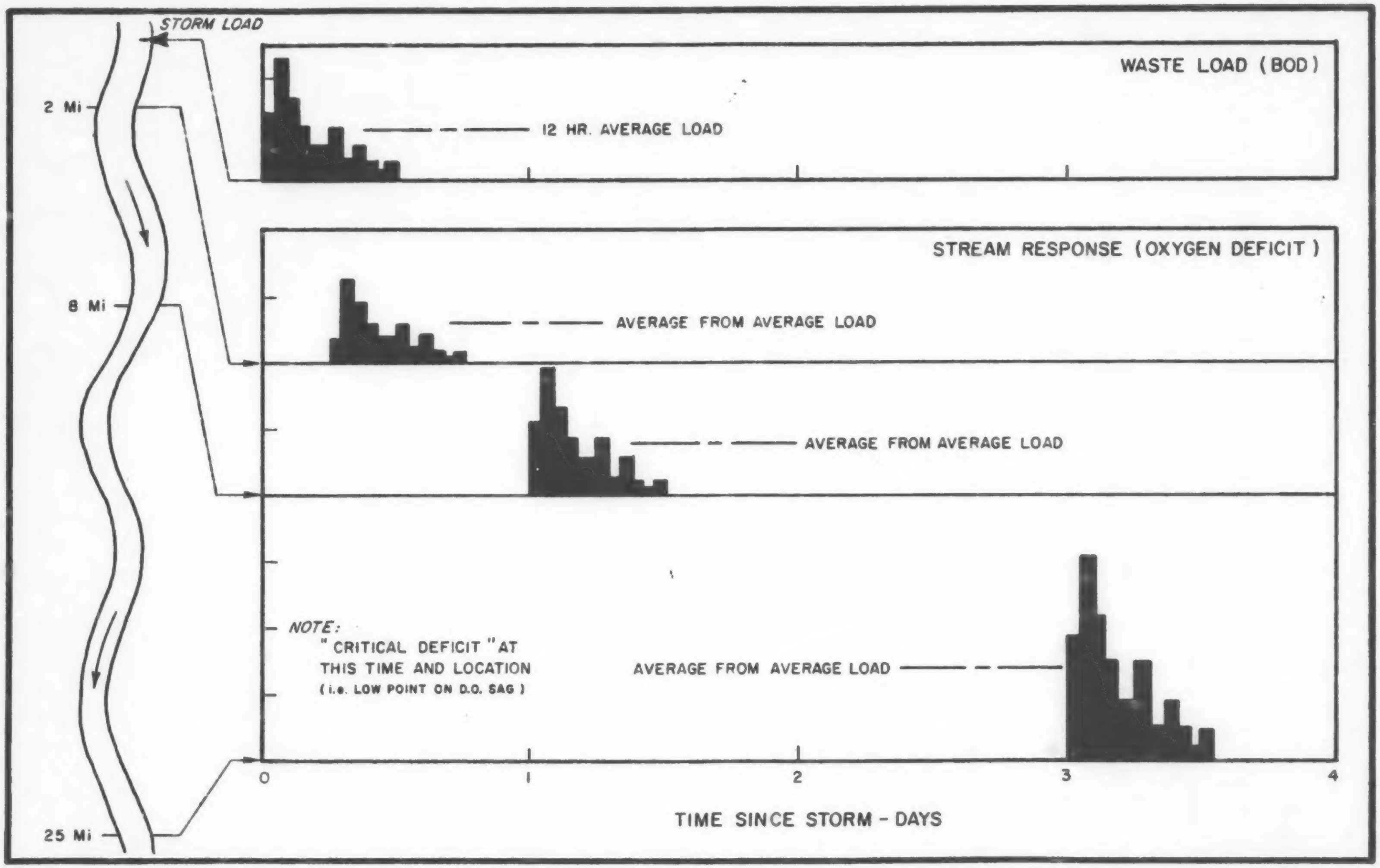

STORM LOAD
2 Mi
8 Mi
25 Mi
WASTE LOAD (BOD)
12 HR. AVERAGE LOAD
STREAM RESPONSE (OXYGEN DEFICIT)
AVERAGE FROM AVERAGE LOAD
AVERAGE FROM AVERAGE LOAD
AVERAGE FROM AVERAGE LOAD
NOTE:
"CRITICAL DEFICIT" AT
THIS TIME AND LOCATION
(i.e. LOW POINT ON D.O. SAG)
0
1
2
3
4
TIME SINCE STORM - DAYS

FIGURE 6

RECEIVING WATER RESPONSE IN ADVECTIVE STREAM

CONCLUSIONS

- There are a wide variety of potential classes instream impacts from storm loads.

- Magnitude and persistence of impacts is influenced by loads and receiving water characteristics.

- The nature of the problem and the nature of the receiving water will strongly influence the control measures which are appropriate - and the most effective way of analyzing the system to make that determination.

- The planning effort should start in the receiving water - and
    - Identify the problem or problems to be addressed.
    - Establish the study approach - data collection, analytical procedures, etc. which will provide the kinds of answers required.

- There is a level of analytical detail which is appropriate in any situation. An effort should be made to identify it and use it. Use of "excessive" levels of detail -
    - a) Are wasteful of resources.
    - b) May limit the completeness of the evaluation.
    - c) Will not necessarily add to the accuracy or reliability of the analysis.
    - d) May "imply" a greater level of accuracy than they really provide.

QUESTIONS AND ANSWERS

(Following Eugene Driscoll's paper "In-stream Impacts of Urban Runoff")

Question: How serious is the urban stormwater pollution problem nationwide?

Driscoll: I don't know.

Condon: You must define what you are studying---whether it is combined sewer overflows or straight stormwater discharges. For combined sewer overflows, there are documented cases where the stream water quality is violated. Then, we must define what constitutes a violation, whether it is a 5-day or 30-day average, or a 24-hour interval. There is a lack of data on the impacts of straight urban stormwater runoff.

Comment (Representative of U.S.G.S., Colorado District): We have now instrumented two basins in the Denver area where we are sampling direct urban stormwater runoff. We are analyzing, chemically, the samples for major cation and anion constitutients and trace metals; and we are making bacteriological examinations. This data will be available, on an annual basis, in our surface water supply papers. Based on our findings this past summer, the basic problem is bacteriological. Dissolved solids are running about 300 mg/l. There are some organic problems but, bacteriologically, we are finding coliforms in excess of 100,000 counts.

Question (Representative of Mountainland 208 Area in Utah): The real problem that we are having with regard to stormwater management is the "objectives". Each group is charged with deciding, for itself, what the objectives really are. We have receiving water standards that are somewhat defined, with only a few parameters. This problem of setting the objectives, or the levels of specific contaminants that will be tolerated, is a real problem area. Without some additional coordination and direction--perhaps nationally or, at least, regionally--I see all sorts of different answers coming out of identical problems. Perhaps you would like to comment on this.

Driscoll: In trying to preserve water quality, somebody had to start somewhere. So, they pulled out some standards. One of the roles of 208 studies can be to identify what costs, alternatives and control measures might be associated with achieving various levels of water quality, and then compare these with the standards to see how realistic the preliminary standards really are.

Comment (Rod Stroope, Seattle Metro): As a further comment on this matter, I feel that the unique nature of Section 208 enables us to look past the standards and try to define our own local water uses and local desires for water quality. That is why I think that overall national impacts of urban drainage come down to, and must be viewed in terms of, unique local situations. I agree that, in order to define a local water quality desire, a great deal of commitment is required by the people who must pay the cost. You talked about the need to define cost-effectiveness in terms of water quality enhancement or incremental degrees of water quality improvement. In order to define that, you first must put it in terms such that the person can pay for it. Also, because of the long term over which degradation occurs, or improvement occurs, it is very hard to quantify.

Driscoll: That's right! I believe that what can be done in the planning process is to identify the cause-and-effect relationships on water quality in a particular receiving water; i.e., relationships between the quality and the various waste loads that result in that quality. Depending on the source of the load, the cost of modifying, controlling or reducing the contamination will vary. It may be much easier to treat a certain contaminant, or source, than another one. The role of the planning process, as I see it, is to clearly identify the relative influences of each of the waste sources on quality and how to estimate the extent to which quality will improve with different levels of control. But a cost has to be associated with that. Then, you should make comparisons with the standards to determine what is real and what is affordable, both on short-term and long-term. People don't want, and shouldn't be asked to pay for some arbitrary level of quality which has no meaning or a low priority when compared to other needs. The people that make the standards and the people that, presumably, modify them really need this kind of information. They didn't have any choices before. Did this answer your question?

Comment (Rod Stroope): No. I still agree with you, but we come down to that classic problem of trying to prioritize water quality problems--not only within the area of urban drainage, but for urban drainage compared with secondary treatment or advanced treatment or other non-point problems.

Driscoll: Prioritizing the problem can have two aspects. One can be considerations of public health and safety. But, in most cases, it is a political decision--not a technical one. The technicians can define only the alternatives --clearly and accurately--for introduction into the political process, so that the public can decide what they can afford and what they want.

Question (Richard Holland, New Mexico): You keep stressing the importance of the relative contribution. Have you been able to come up with that "reasonable" data on which public officials can make their judgements? I am speaking, both, of stormwater drainage as a contaminant vis-a-vis the other sources of contaminants--also the causes, within the category of stormwater drainage, of the particular contaminants that prove to be a problem, in order to identify what can be done. Have you been able to do this within the studies you have done.

Driscoll: I think so. But there is a limit.

Question (Richard Holland): Can you give a few examples, in specific areas you investigated, of the relative impacts of stormwater, versus other sources --for any particular contaminant, or combination thereof?

Driscoll: We are doing a 208 study for the Salt Lake City area. We identified the municipal point-source discharges and determined that they account for a relatively small percentage of the total dissolved oxygen problem that we identified. We have not determined exactly what is contributing to the DO deficiency--whether it is accumulated sediments, stormwater discharges agricultural returns or other factors. But, this is the sequential process that we are following.

Athayde: I would like to respond to a question raised this morning by a gentleman from Utah. It dealt with the levels of quality that we could expect from urban stormwater runoff. I think that you must first identify which pollutant is making the stream water quality limited. Next, you should find out how much of an impact you can have on that particular pollutant. It may be of such magnitude that the impact can't be very much. You must keep in mind that we are stressing non-structural techniques and that there, probably, won't be any funding for stormwater control. Paul Ferraro, who is with EPA Region VIII, said that he also would like to respond to this question.

Comment (Paul Ferraro, EPA Region VIII, Denver): I understand Laverne's question. It is quite broad and has to do with the whole water quality standards problem. It does not relate only to urban runoff. We recognize this as a significant problem in all of our 208 study areas. The Colorado Springs study started over a year ago. They identified water quality standards and brought this up as an issue. I have discussed the general approach that I like with the 208 agency in Colorado Springs and the State staff. This approach is that we utilize the criteria that is coming out in the blue book to set the standards for 1983. Many present water quality standards will not meet the 1983 goals. It is also necessary to keep in mind that the State is required, every three years, to revise its water quality standards. I feel that the 208 agencies can provide the necessary information so that the standards can be revised at the required times. Our standards expert with EPA Region VIII is Dale Polnow. Dale, do you wish to add anything?

Comment (Dale Polnow, EPA Region VIII): I think that you covered it Paul. I would like to point out that this revision process will get underway at the beginning of 1976. It is to be completed in, about, a one-year time frame. I think it is important for 208 agencies to look at their streams, their problems and their uses, and to start getting this information into a form that can be fed to the states for use in the standards-making process.

Ferraro: Roy, do you have any response to this?

Comment (Shelby Noll): Our difficulty is in determining how much data we need to collect to show that we have a significant problem. We started a year too late in collecting data. We should have started on the first day of our study period. We would like to know what constitutes an adequate data collection base for both point and non-point sources and ambient water quality. We would also like to know what proportion of Region VIII budgets should be spent on such data collection.

Athayde: Perhaps John Kingscott of our Washington, D.C. Water Planning Division, EPA, could shed some light on this.

Comment (John Kingscott): Obviously, the more data we have--the more competent we can be. It is very important to realize that we are limited, primarily, in our time frame. We have two-year, legislated periods to do the planning and we are expecting the data gathering and analysis to be completed within a year so the information can be used. This limits the kind of monitoring program that we can expect to implement.

Comment (Richard Field): If, in a one-year period, we can collect enough data to verify within reason the planning models available, we could go back in time and use available rainfall records and, thus, work with more than one year of data.

Athayde: If anyone has wrestled with this problem and developed an approach, I certainly would like to hear about it. I have an example here done by the

Smithsonian Institution for the Rogue River Watershed, in Maryland. They did a characterization of a non-point pollution problem in one year. They had five subbasins within the watershed. They installed five monitoring stations and monitored five pollutants. I reviewed this study and found it to be an adequate representation. A copy is on display on the speakers' table for your perusal.

IMPACT OF CSO/SSD ON WATER QUALITY

by

John A. Lager, Vice President
Metcalf & Eddy, Inc., Palo Alto, California

INTRODUCTION

The impact of combined sewer overflows and storm sewer discharges on receiving waters is one of the most poorly defined and under-investigated monitoring areas in our nation's surveillance program. While the problems are manyfold, three are believed dominant:

- The causes are intermittent and uncontrolled and the impacts largely transient
- In the past, dry-weather wastewater discharges have so dominated receiving water conditions, that wet-weather impacts were largely masked or unrecorded
- The costs of wet-weather monitoring are prohibitive and to a great extent dependent upon fully automated sampling stations

As a result, past investigations have been limited largely to gross impacts of aesthetics, contamination, and point source loadings.

Aesthetics

It is human nature to judge a water's purity by its appeal to our senses of sight and smell. Where gross pollution occurs, who would question our ability to identify such areas through pictures such as these (series of slides of CSO discharges on beaches and waterfronts)?

Public Health Concerns

Where water contact is a beneficial use, the safety or freedom from contamination is measured in terms of plate or filter counts of indicator organisms--coliforms, fecal coliforms, etc. Measurements above certain arbitrary levels then classify such waters as safe or unsafe. Obviously, if counts rise during and following storms, the impacts may be traced to the CSO/SSD discharges and the beaches closed until safe conditions again prevail.

Point Source Loadings

Gross point source loadings may be evident through the formation of sediment and sludge banks, the scouring of benthic deposits, color and turbidity profiles and patterns, and detected changes in continuously monitored parameters. Also, the prevailing life forms in certain sections of streams and their seasonal variability may be traceable to CSO/SSD.

QUANTIFICATION OF IMPACTS

Receiving water impacts of wet-weather discharges have been broadly quantified by a few investigators. The following examples are believed representative.

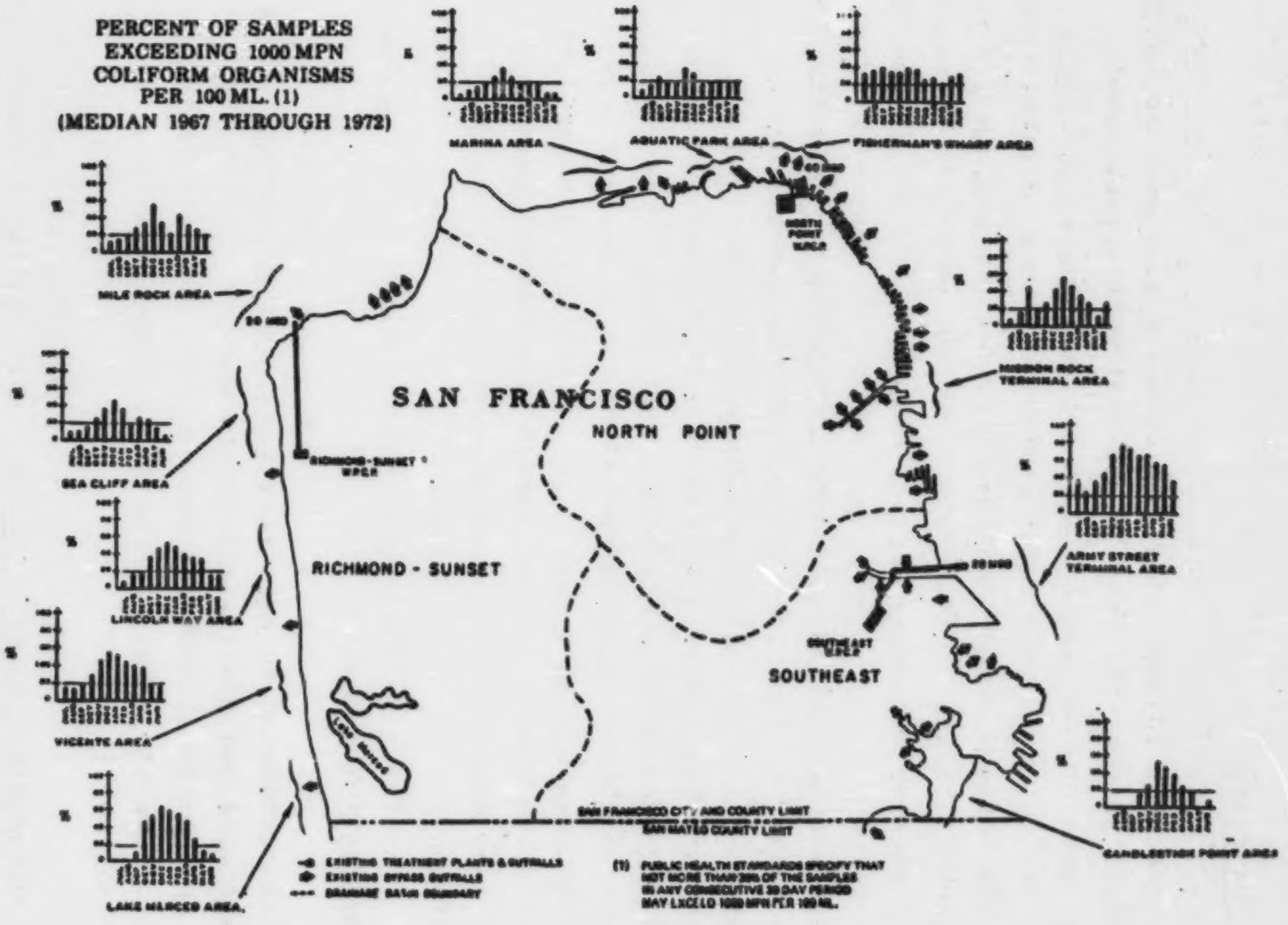
San Francisco

San Francisco is sewered on the combined plan and its annual rainfall pattern is strongly seasonal with approximately 95 percent of the rain occuring between October and April. As a result, receiving water comparisons between predominantly wet and predominantly dry conditions are readily discerned. Beaches on the San Francisco peninsula shoreline are posted by the San Francisco Department of Public Health from October to April each year due to the contamination from waste discharges, principally overflows. Coliform data collected from 1967 through 1972 is summarized in Figure 1 [1]. Typically, coliform levels observed at beach sampling stations increased 6 to 7 times in changing from dry-weather to wet-weather conditions. Upon cessation of wet weather, values decreased to the background dry-weather levels within five days. Similarly, average flotable particulate concentrations immediately off the beaches increased approximately 7 times under the wet-weather conditions.

Minneapolis-St. Paul

The EPA conducted an extensive river sampling survey of the Minneapolis and Mississippi Rivers through the Minneapolis-St. Paul metropolitan area between June 1964 and September 1965. A brief summary of the river water quality at that time follows [2].

> Mississippi River at Anoka. This was the upstream point in the survey (about 10 miles from the city center). Water quality was generally good, the water was high in DO (7.9 mg/l), low in BOD (3.0 mg/l); low in turbidity; and no visible signs of pollution, such as floating solids, liquids, or excessive color. These conditions



PERCENT OF SAMPLES
EXCEEDING 1000 MPN
COLIFORM ORGANISMS
PER 100 ML. (1)
(MEDIAN 1967 THROUGH 1972)
%
MARINA AREA
AQUATIC PARK AREA
FISHERMAN'S WHARF AREA
NORTH POINT W.P.C.P.
MILE ROCK AREA
MISSION ROCK TERMINAL AREA
SAN FRANCISCO
NORTH POINT
SEA CLIFF AREA
RICHMOND - SUNSET W.P.C.P.
ARMY STREET TERMINAL AREA
RICHMOND - SUNSET
LINCOLN WAY AREA
SOUTHEAST W.P.C.P.
SOUTHEAST
VICENTE AREA
LAKE MERCED
LAKE MERCED AREA
SAN FRANCISCO CITY AND COUNTY LIMIT
SAN MATEO COUNTY LIMIT
CANDLESTICK POINT AREA
EXISTING TREATMENT PLANTS & OUTFALLS
EXISTING BYPASS OUTFALLS
DRAINAGE BASIN BOUNDARY
(1) PUBLIC HEALTH STANDARDS SPECIFY THAT NOT MORE THAN 20% OF THE SAMPLES IN ANY CONSECUTIVE 30 DAY PERIOD MAY EXCEED 1000 MPN PER 100 ML.

Figure 1. MONTHLY COLIFORM COUNTS [1]

> prevailed except for a steady increase in coliform values, down to St. Anthony Falls close to the city center, but above major combined sewer outfalls.
>
> Mississippi River-St. Anthony Falls to dwf Treatment Plant Outfall. During dry weather, the water quality in this segment of the river was essentially the same as in the preceding segment. However, during and immediately after rainfall, discharges from some or all of more than 80 combined sewer overflows caused a deterioration in river water quality. Deterioration was in the form of turbidity (increase from 25 units to 60 units), and coliform densities (exceeded all limits for various water uses). Even the use of these waters for boating, fishing and navigation was considered to constitute a health hazard.
>
> Mississippi River-dwf Treatment Plant Outfall to Point 20 Miles Downstream. DOs decreased progressively from an average of 7.5 mg/l at the plant (offering only primary treatment at the time) to values of less than 1.0 mg/l 15 miles downstream, below which the DO started to increase. During low-flow conditions in August 1964, gas bubbles, floating sludge, and oil slicks were observed. There were also dense growths of fungi along the shore lines.
>
> The next river segment was a part of the pollution recovery zone as the natural purification processes came into effect, and as less contaminated streams contributed their flows.

The above descriptions represent a classical river system-urban development situation. While the scales of this test case are large (riverflow 10,000 cfs and population 1.8 million), they may easily be visualized down to the smallest creek and discharge relationship.

Greater Seattle

Harper et al [3] recently studied the effects of urbanization, in particular stormwater runoff, on the water quality characteristics in Miller Creek (5,230 acres) and Des Moines Creek

(3,730 acres) watersheds. The watersheds are characterized as about 20 percent single family residential, 35 percent multi-family residential, 10 percent commercial and the remaining land is open space or agricultural. Approximately 25 to 30 percent of the area is impervious.

The impact of stormwater discharges on the creeks were qualitatively assessed as follows:

> Generally for both creeks, the following increases in concentration of constituents were measured: BOD, 4 mg/l; PO_4, 0.5 to 1 mg/l; total solids, 20 to 30 mg/l; turbidity, 10 to 30 FTU; and color, 80 to 120 Pt-Co units. Significant increases in zinc in Des Moines Creek and lead, copper and zinc in Miller Creek were also measured and can be attributed to stormwater discharges. The concentrations of all other parameters either decreased or did not significantly vary to identify stormwater as the sources of these contaminants.

It was further observed that while the BOD increased significantly, there was no apparent impact on the dissolved oxygen because the re-aeration of the creeks also increased due to the higher velocities and turbulance.

Stormwater impacts were also assessed by measures of the biological communities within the creeks. While some toxicity was believed occurring from stormwater discharges (metals, solids, oil and grease), it was believed that changes in the communities were more a result of changes in stream discharges. Scouring of streambanks by the increased flows compounded sedimentation problems and were of a scale equal to or greater than sediments brought in through the stormwater discharges.

Other qualitative studies are available for Bucyrus, Ohio; Roanoke, Virginia; and Castro Valley, California [4].

ASSESSMENT TECHNIQUES

The impact of CSO/SSD on receiving water quality requires the before, during and after comparison of in-stream parameter values under varying hydrologic, development, and control alternative conditions. The logical tool for such analyses is the mathematical model. In a recent Journal article, Hines et al [5], present an excellent discussion of the potentials and limitations of models for such applications. Figure 2, taken from the article, rates the relative difficulties of modeling with impact objective.

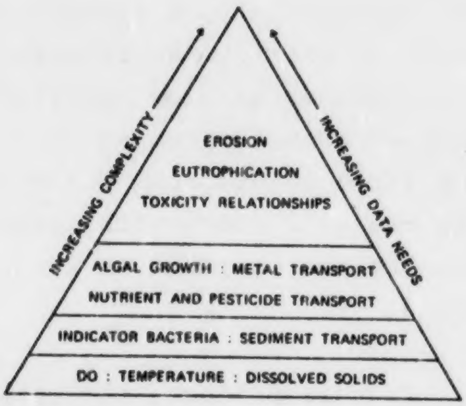

INCREASING COMPLEXITY
INCREASING DATA NEEDS
EROSION
EUTROPHICATION
TOXICITY RELATIONSHIPS
ALGAL GROWTH : METAL TRANSPORT
NUTRIENT AND PESTICIDE TRANSPORT
INDICATOR BACTERIA : SEDIMENT TRANSPORT
DO : TEMPERATURE : DISSOLVED SOLIDS

Figure 2. RELATIVE DIFFICULTY OF APPLIED MODELING [5]

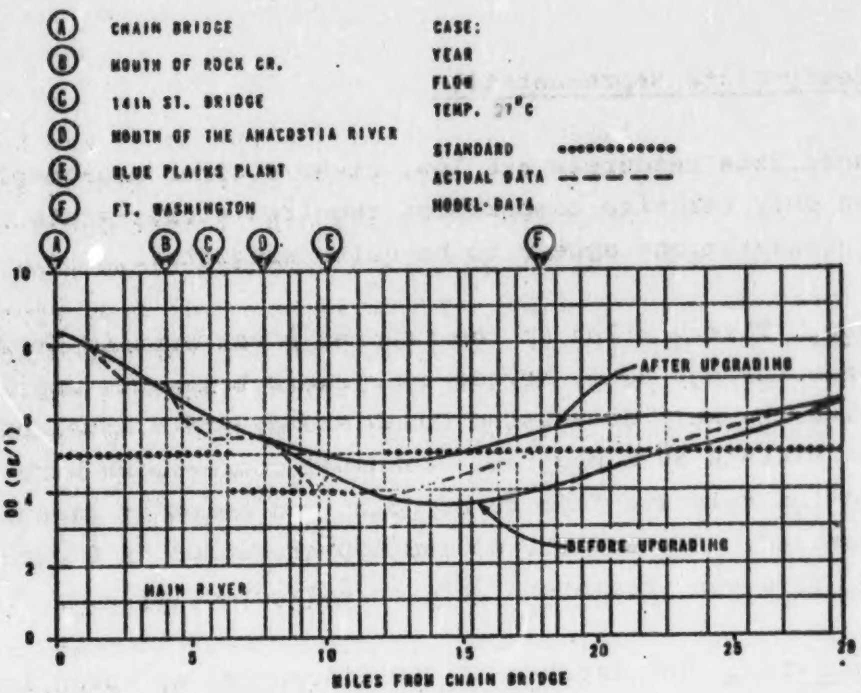
The authors conclude that a river quality model can be a powerful predictive tool for river basin planning and management providing that premises and limitations are recognized, and that the model is properly formulated, calibrated, and verified. Selected material from approaches we have used are presented briefly in the following sections. Details of the models and their applications are the subject of a later lecture.

Transient Impacts

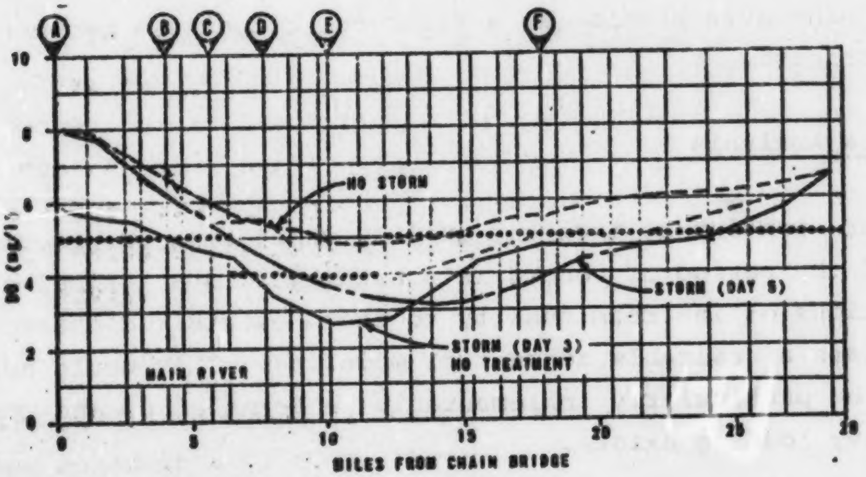
Models used to portray transient conditions attempt to answer the question of what happens during and immediately following a storm in complex river systems or estuaries. They are dynamic in principal, and the data requirements can be extensive.

Washington D.C. In this project, a dynamic (SWMM) receiving water model of the Potomac estuary was used to represent critical summer quarter conditions. Superimposed on this base were the upgrading of the regional dwf treatment plant (from 90-98% BOD_5 removals) and the impact of a once in two year storm with alternative controls in effect. The results are compared to the receiving water standards in Figure 3.

Chicago, Illinois. In this project, the constaints were in both quality and quantity (backflow to Lake Michigan was to be avoided even under the largest storms of record). Thus, even though a relatively simple river network was modeled (approximately 75 miles), the flows examined were so extreme as to cause localized reversals in direction, and a dynamic representation was required.



IMPACT OF UPGRADING REGIONAL PLANT



IMPACT OF 2-YEAR STORM WITH UPGRADED PLANT

Figure 3. TYPICAL DYNAMIC MODEL RESULTS,
POTOMAC ESTUARY

Steady-State Representation

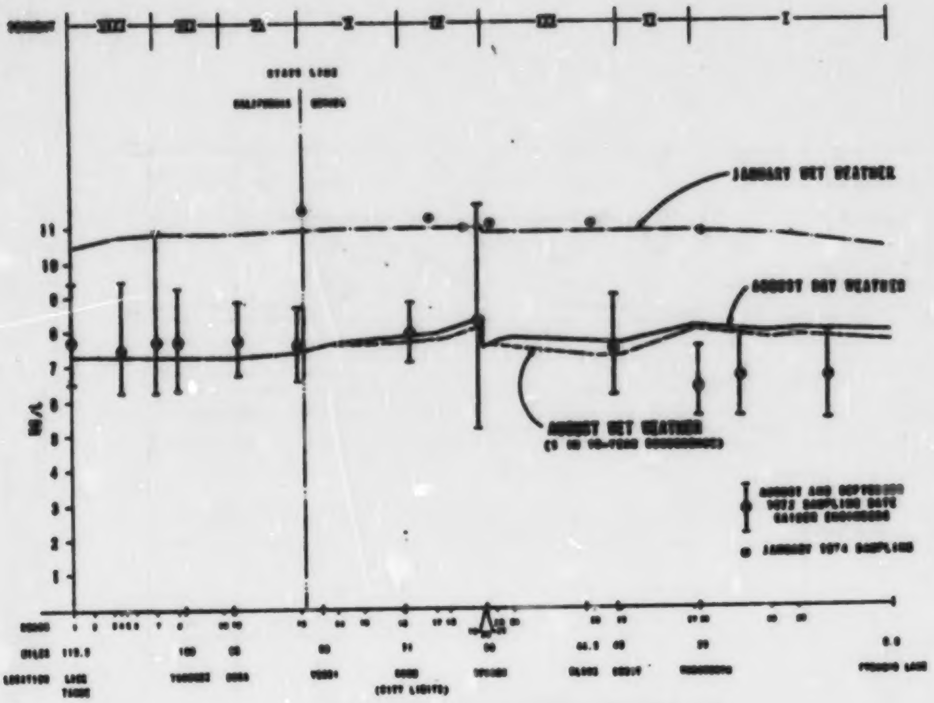
Where data resources are low, river regimes non-complex, and only relative comparisons required steady-state representations appear to be quite adequate.

Reno. Thirty miles of the Truckee River running from Lake Tahoe through Reno, Nevada to Pyramid Lake were modeled using the well documented DOSAG steady-state model under the state's 303e program. Seasonal comparisons were made and the relative impacts of point and nonpoint discharges assessed. Results for DO and BOD are shown in Figure 4. In all seven parameters were investigated [6].

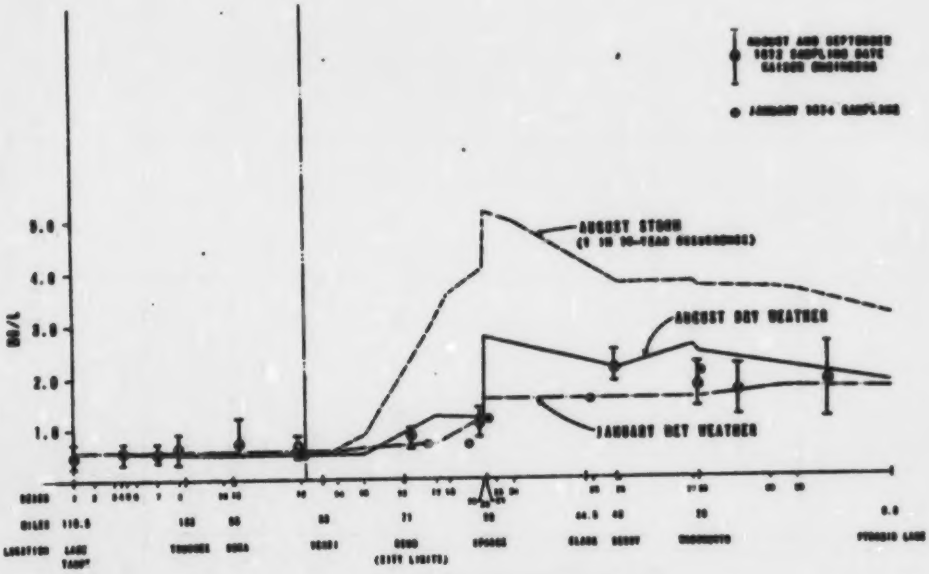
Rochester. The impacts of CSO discharges at seven locations in the lower 15 miles of the Genesee River are being modeled using simple steady-state assumptions [7]. The results for large discharges, shown in Figure 5, show considerable promise as a first-cut comparison between alternatives.

Data Analysis

Where continuous instream quality monitoring is practiced and the period of record is substantial, statistical correlations of instream quality to storm events and character offers a desirable adjunct to modeling. This would appear to be particularly implementable in terms of DO and where heavy loading exists.



EXISTING DISSOLVED OXYGEN CONCENTRATIONS



EXISTING BOD CONCENTRATIONS

Figure 4. TYPICAL STEADY STATE MODEL RESULTS, TRUCKEE RIVER

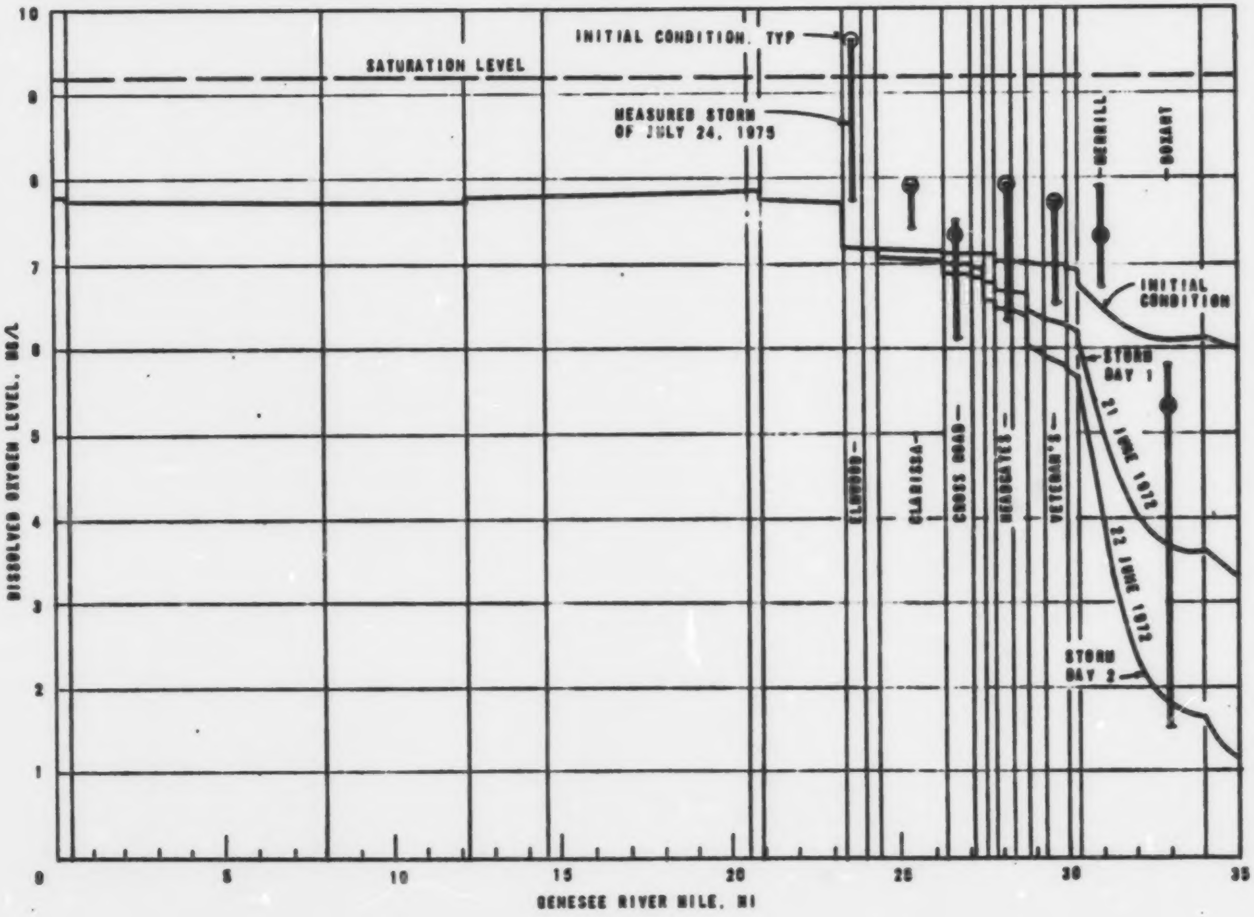


Figure 5. TYPICAL STEADY STATE MODEL RESULTS FOR DISSOLVED OXYGEN IN GENESEE RIVER

CONCLUSIONS

The impacts of CSO/SSD on receiving waters need greater attention and quantification. Beyond the obvious gross impacts, continuous monitoring at key locations offers the best potential for identifying trends and sources. Modeling, at its present stage of development and with the available data base, offers a viable tool for comparing major alternatives. Modeling and data collection, with rare exception, should be held to the simplest level compatible with the objective decision making.

REFERENCES

1. J.B. Gilbert & Associates with Metcalf & Eddy, Inc. Evaluation of San Francisco Wastewater Master Plan. Prepared for the Department of Public Works. March 1973.

2. Metcalf & Eddy, Inc. Sewerage and Water Planning Report to the Metropolitan Council of the Twin Cities Area. November 1968.

3. Harper, M.E., E.B. Welch, T. Weiderholm, and B. Perrot. Degradation of Urban Streams from Stormwater Runoff. (Presented at Second Annual National Conference on Environmental Engineering Research, Development, and Design. University of Florida, Gainesville. July 20-23, 1975).

4. Lager, J.A. and W.G. Smith. Urban Stormwater Management and Technology - An Assessment. Metcalf & Eddy, Inc. U.S. Environmental Protection Agency Report EPA-670/2-74-040. December 1974.

5. Hines, W.G., D.A. Rickert, S.W. McKenzie, and J.P. Bennett. Formulation and Use of Practical Models for River Quality Assessment. Journal of the Water Pollution Control Federation. October 1975.

6. Walters Engineering with Metcalf & Eddy, Inc. Areawide Water Quality Management Plan, Washoe County, Nevada. Washoe Council of Governments. November 1974.

7. O'Brien & Gere Engineers, Inc. Combined Sewer Overflow Abatement Program, Rochester, N.Y. EPA Grant Y005141 to Rochester Pure Waters District. June 1974.

QUESTIONS AND ANSWERS

(Following John Lager's paper "Impact of Combined Sewer Overflows and Storm Sewer Discharges on Water Quality")

Question (Richard Field, EPA, Edison, N.J.): Have you given any thought to certain kinds of pollutants that are not usually sampled or measured in a conventional water quality survey--such as floatables and heavy solids? These are highly significant pollutants, affecting aesthetics; and they produce delayed contribution to BOD loads, siltation, et cetera. Modeling, usually, does not take account of these pollutants.

Lager: The question relates to two of the areas of contamination that I mentioned and stressed very highly--floating matter and particulate matter that really aren't monitored and aren't logged on STORET. My recommendation for an approach to this is to use a camera. The best way of recording some impacts is through photography. It shows the degree of the problem and why the prolem may be concentrated in one area--such as backwater areas where the pollutants aren't flushing through. I think that aerial reconnaissance is also applicable here. It is used to pick up zones of influence of discharges, particularly industrial wastes. Maybe the same techniques can be applied to stormwater discharges to determine the sources of concentrations of sediments. A key is to get out on the system and use your eyes and not be solely confined to desktop analysis or numerical analysis.

NON-POINT SOURCE IMPACT AND URBAN HOLDING CAPACITY

by

G. Kenneth Young

GKY & Associates
4900 Leesburg Pike, Suite 311
Alexandria, Virginia 22302

November, 1975

Introduction.

The objectives are: to present a simple model that attempts to encompass waste generation and receiving water quality; to identify the impacts of control options that this model implies; to focus on the effects of density in the urban area; and, finally, to discuss some of the major issues.

It seems to be popular these days to discuss very complicated models and data bases to the point where we lose perspective. So, I am attempting to provide a wide angle focus in order to gain an overall perspective. A simple model is used in order to be concrete.

An analogy is that my broad brush method is an attempt at a holistic approach. "Holism" is a term that has been used by ecologists to describe an analysis that encompasses an entire system and gives equal balance to the various components of it with the thought that you have to study all parts of a system; and study of any part of it is inadequate to understand the whole. It is a relatively new concept and one that is somewhat anti-scientific, because scientists must, by the nature of the scientific method, focus in on very detailed, almost minute, issues to gain more and more understanding. But, as we get into complex systems that involve all of us and where and how we live, it seems important to synthesize all the ecosystem components, some of which are poorly understood, and attempt to balance analysis of their interactions.

Simplified Average Water Quality Model.

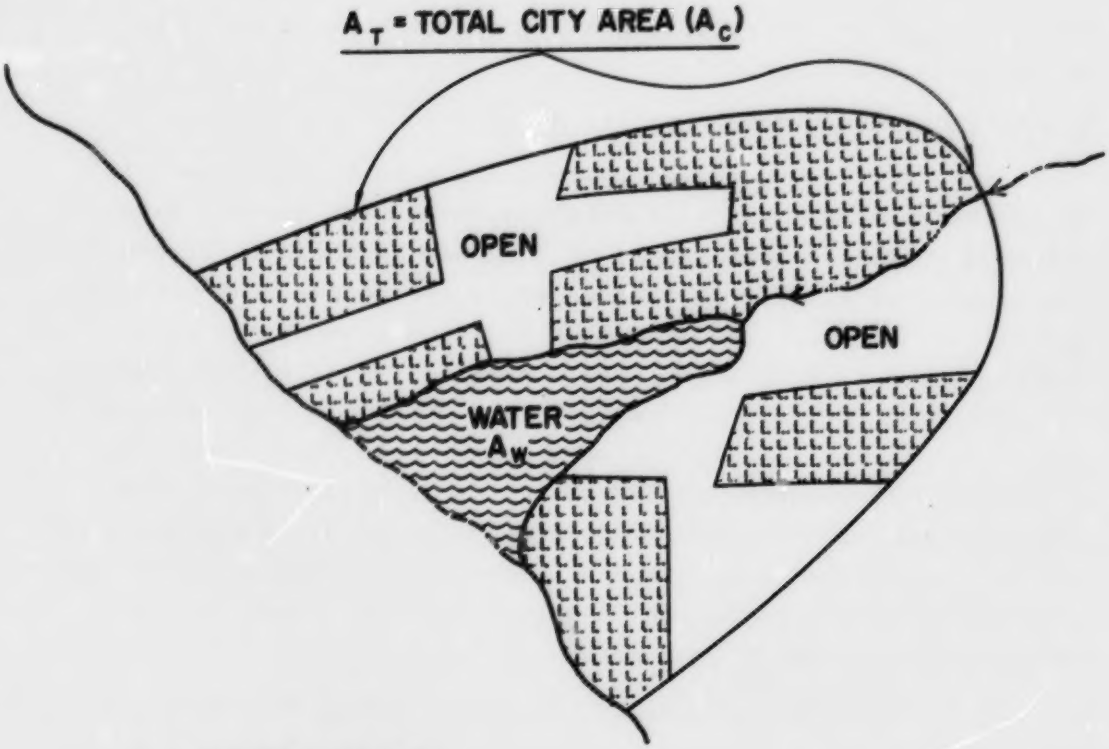
As part of the holistic approach, and, in this context, it is necessary to make major simplifications. The model I have selected considers three types of land use as shown in Figure 1. One is an open water body that is to be ecologically and environmentally protected. The second is the shaded developed area, and the third is open area. The population is distributed on the developed area with a density "D". The ratio $\frac{\text{"P"}}{D}$ defines the amount of the developed area in acres and "Total Area minus $\frac{P}{D}$" defines the undeveloped land. In any developed area, and in many of these urban runoff studies that are being conducted, this type of conceptualization is disaggregated to produce a much finer level of detail encompassing different types of developed land and different types of open space.

To analyze the capacity of the water body in the center of this developed land, Figure 2 shows a simple steady-state "oxygen-demand model" which can be derived from more complicated representations. The amount of oxygen that can go into this water surface, in terms of pounds-per-day, is proportioned to the area of the water surface and the quantity (S-C) which is termed the "dissolved oxygen deficit". "S" is the maximum amount of oxygen that the water can hold. It is normally a small amount, 10 mg/l or 10 ppm. "C" is the actual dissolved oxygen in the water as a result of pollutional loads that enter into it. The difference between the maximum amount of oxygen and the actual amount of oxygen in the water provides a driving force for oxygen to enter the water across the air-water interface. Thus, the amount of dissolved oxygen is proportional to the water area, the dissolved oxygen deficit, an oxygen transfer coefficient K_L (having units of feet/day) and 2.71 which is a conversion factor to make the units work out.

There are numerous experiments and publications[1] that give

---

[1] Environmental Protection Agency, "Simplified Mathematical Modeling of Water Quality" a report by Hydroscience, Inc. March 1971.


A_T = TOTAL CITY AREA (A_C)
OPEN
OPEN
WATER
A_W

P = POPULATION

D = DENSITY (PEOP/A_C)

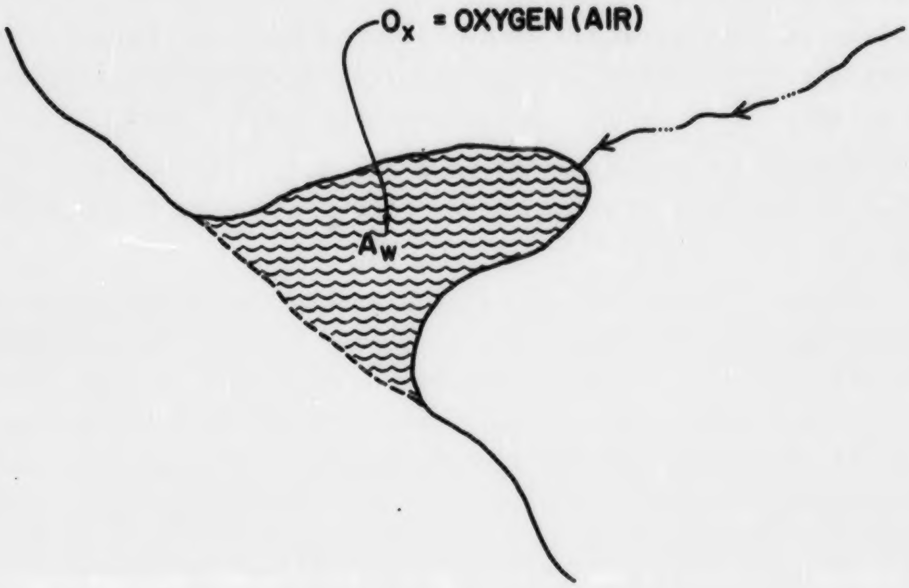
$\frac{P}{D}$ = ▨ = DEVELOPED LAND

$A_T - \frac{P}{D}$ = $\boxed{\text{OPEN}}$ = UNDEVELOPED LAND

FIGURE 1

LAND USE

$$\boxed{O_X = 2.71\ K_L\ A_W\ (S-C)}$$



O_X = OXYGEN INPUT (LBS/DAY)

A_W = WATER SURFACE AREA (ACRES)

S = SOLUBILITY OF OXYGEN (mg/l)

C = AVERAGE DISSOLVED OXYGEN (mg/l)

K_L = O_X TRANSFER COEFF (FT/DAY)

FIGURE 2

SIMPLIFIED STEADY STATE MODEL

wide ranges to the coefficient K_L which is a function of many different physical mechanisms. Also, I am neglecting some water quality parameters and I am considering only the oxygen. Other important parameters, in an ecological context, would be the nutrients, oil, solids, toxic materials, and others.

The amount of oxygen shown in Figure 2 which enters the water is directly related to the amount of waste discharged to the water.

Figure 3 gives the waste generation from a developed area, which also has rainfall; this curve has a floor for the point-source, with a series of peaks that correspond to storm events that induce non-point source inputs. On the East Coast and the Florida area which inspired this example[2], the time between successive rains or peaks is three days, plus-or-minus. I understand that at Boston it is two days, plus-or-minus. In dry areas it could be weeks, depending on the time of year.

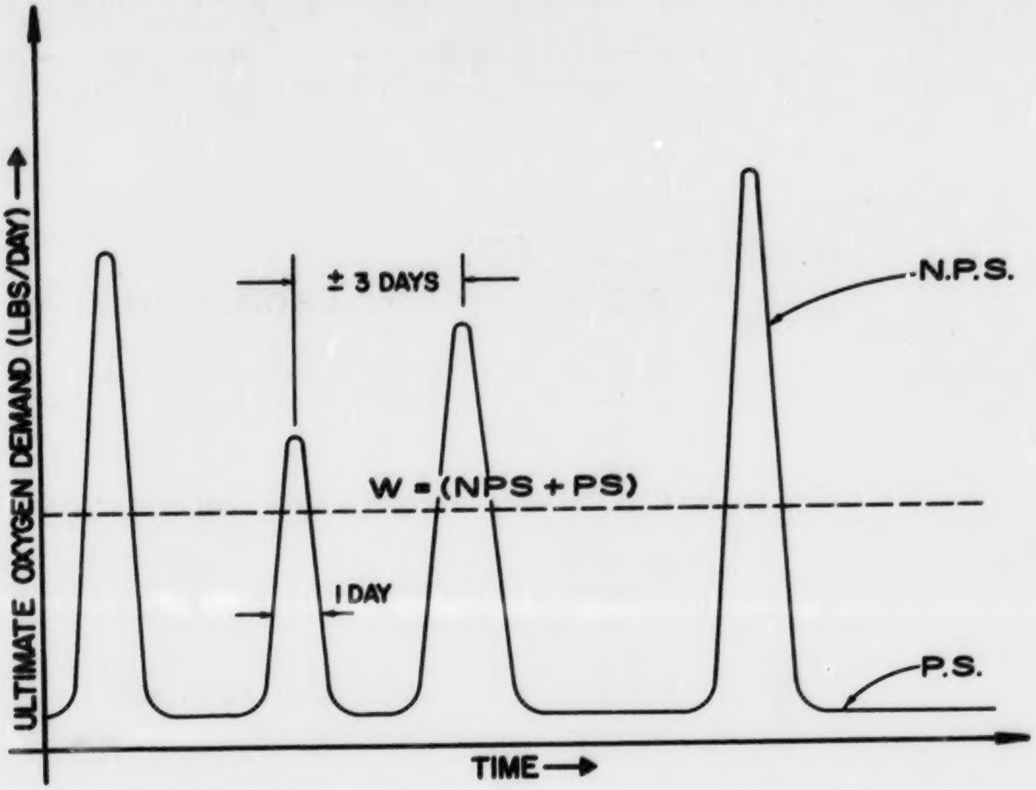
To complete the simple model we take the point-source loads, and average them to obtain an "average effective waste input", W, comprised of the non-point source and point-source loads. The relationships are given in Figure 4. The "ultimate oxygen demand", in pounds per day, is considered; this is an indirect measure of the organic material going into the system. With "W" being the "average daily waste" at steady state, the waste input equals the amount of oxygen that can enter into the system. To estimate W, it is assumed that the developed land possesses a loading factor, L_D, in terms of pounds of UBOD per-acre/day. This is an average of the total arrival emissions caused mainly in wet periods divided by all days in the year. There is the same type of loading factor for the open space.

The point source, in this case, is caused by people; domestic waste loading is normally expressed in pounds-per-capita per day.

Recall that we have P as "population", D as the density in

---

[2] Sanibel Island, Lee Co., Fla.; the water body is a fresh water marsh in the center of a barrier island.



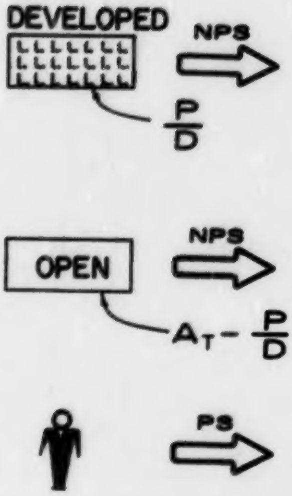
W = AVERAGE DAILY WASTE (NPS + PS)

A_T = EQUILIBRIUM ⇒ $\boxed{W = O_x}$

FIGURE 3

WASTE AVERAGING

$$W = \underbrace{L_\phi (A_T + A_W) + (L_D - L_\phi)\frac{P}{D}}_{NPS} + \underbrace{(1-f) L_P P}_{PS}$$


DEVELOPED
NPS
$\frac{P}{D}$
OPEN
NPS
$A_T - \frac{P}{D}$
PS

L_D = LBS UBOD/ACRE/DAY

L_ϕ = LBS UBOD/ACRE/DAY

L_P = LBS/CAPITA/DAY

P = POPULATION; D = DENSITY (P/ACRE)

FOR PS → f = fraction removed

FIGURE 4

WASTE GENERATION MODEL

"people-per-acre". We introduce another variable "f" which is the fraction removed of the point source. With these parameters, I can multiply the loading factors times the areas and get a waste generation function which gives the average waste input per day as a function of the non-point source upon the developed and open lands, plus the point source (or 1 minus f, times the per capita loading rate times the population).

The ratio of developed-to-undeveloped loading rates can be on the order of 10 to 100. The developed loading rates are strongly related to the ratio of pervious and impervious area. In open space, most of the water sinks in, and you get a soil removal process. Thus, the loading rates are much smaller.

Application of the Model.

For a typical Florida situation where we were attempting to develop holding capacity constraints, we used the typical values shown in Table 1 for the parameters. The desired average dissolved oxygen, or the water quality standard, is 5-mg/liter; the dissolved oxygen solubility is 9 mg/l (this is typical of warm southern waters); the oxygen-transfer coefficient is 0.15 feet/day (this is representative of quiet, still waters). For waste generation, in open land for the non-point source, 0.004 pounds/acre/day of UBOD is used (yearly average); for the developed land, non-point source loading, 0.4 pounds/acre/day of UBOD is used. For the point-source loading, we use 0.25 pounds/capita/day which is more-or-less a U. S. average for domestic untreated sewage. We have a point-source removal fraction of 0.85 which corresponds to the secondary treatment level required by P.L. 92-500. And, for this Florida demographic situation, there was a total land area of about 5,000 with a fresh-water marsh of 1,000 acres, a population of 12,000, and a density of 4 persons per acre (which is rather low and which would correspond to an affluent suburb).

When I combine these relationships and values into the holistic model that I referred to, I get the average concentration of the dissolved oxygen in the water body (in this case, a marsh); the

TYPICAL VALUES

	PARAMETER	SYMBOL	COMMENT
QUALITY	Avg. D.O.	$C = 5$ mg/l	Typical W.Q.S.
	D.O. Solubility	$S = 9$ mg/l	Southern
	D.O. Coefficient	$K_L = 0.15$ ft/d	Quiet, still
WASTE GENERATION (U.S. AVERAGE)	Open N.P.S.	$L_\phi = .004$ #/Ac/d	Yearly Average
	Developed N.P.S.	$L_D = .4$ #/Ac/d	Yearly Average
	P. S.	$L_P = 0.25$ #/CAP/d	U. S. Average
	P.S. Removal	$f = 0.85$	PL 92-500
DEMOGRAPHIC (FLORIDA)	Total Area	$A_T = 5000$ Ac	
	Water Area	$A_W = 1000$ Ac	
	Population	$P = 12000$ P	
	Density	$D = 4$ P/Ac	Affluent Sub.
	Open Space	$5000 - \frac{P}{D} = 2000$ Ac	

TABLE 1

waste-generation function equals the oxygen-transfer function. This function is given in Figure 5. Then, I calculate the partial derivatives (or the marginal rate-of-change) of the dissolved oxygen concentrations, with respect to the more popular policy-sensitive variable. Figure 5 shows the rate-of-change of the concentration with respect to the population (small and negative), the rate of change with respect to the density (large and positive), the rate of change of dissolved oxygen concentration with respect to the removal fraction, the rate of change of C with respect to the land use loading factor emission rate for developed land (fairly large) and the rate of change with respect to the water surface area (rather small).

These coefficients are hard to compare among themselves. But, they can be combined into a relationship using the total differential, or the first-order terms of the Taylor Series Expansion, and you get the change in "C" for changes in the various parameters. That is the type function which permits you to assess the impacts of various policy options.

Table 2 puts this sensitivity information into a scaled format which makes changes relative and more interesting. I can scale the policy-sensitive variables, plus-or-minus 10%, as the case may be, to get positive changes in water quality. So, if I decrease my population by 10%, I can improve the average water quality in the system by 7.9%. If I increase the water area 10%, or the assimilative capacity, I can increase the dissolved oxygen by 7.6%. If I decrease the non-point source load by 10% (for the developed areas), I get an increase in dissolved oxygen of 5.9%. If I increase my density 10% (I keep the same number of people, but put them on less land), I get 5.8% increase in dissolved oxygen. If I decrease my point-source load by 10%, I get a 2.2% increase in dissolved oxygen.

A change in the water area would correspond to some type of increase in the assimilative capacity. This is a classical solution and since the 1900's we have connected our sewers and sewage treatment plants to points that are further downstream having increased assimilative capacity.

$$\boxed{W = O_X}$$

$$\downarrow$$

$$\boxed{C = S - \frac{L_\phi (A_T + A_W) + (L_D - L_\phi)\frac{P}{D} + (1-f) L_P P}{2.71 K_L A_W}}$$

PARTIAL DERIVATIVES

$$\frac{\partial C}{\partial P} = -0.00033$$

$$\frac{\partial C}{\partial D} = +0.73$$

$$\frac{\partial C}{\partial f} = +7.38$$

$$\frac{\partial C}{\partial L_D} = -7.38$$

$$\frac{\partial C}{\partial A_W} = +0.0038$$

$\Delta C \cong$ TOTAL DIFFERENTIAL

$$\Delta C = -.00033\ \overset{\text{POPULATION}}{\Delta P} + 0.73\ \underset{\text{DENSITY}}{\Delta D} + 7.38\ \overset{\text{P.S. REMOVAL}}{\Delta f} - 7.38\ \underset{\text{N.P.S. LOAD (DEVELOPED)}}{\Delta L_D} + 0.0038\ \overset{\text{WATER SURFACE}}{\Delta A_W}$$

FIGURE 5

WATER QUALITY SENSITIVITY

PARAMETER (TYPICAL VALUE)	CHANGE IN PARAMETER	CHANGE IN AVG. D.O.
POPULATION (P = 12000)	-10%	+7.9%
WATER AREA (1000 ACRES)	+10%	+7.6%
NPS LOAD - #/D* (71.5% TOTAL LOAD)	-10%	+5.9%
DENSITY (P.ACRE = 4)	+10%	+5.8%
PS LOAD - #/D (27.1% TOTAL LOAD)	-10%	+2.2%

*Developed Areas

RELATIVE IMPACT

TABLE 2

Decreasing the non-point source load is definitely an option. It may be possible to achieve this through urban housekeeping techniques or improved grading practices. However, it takes imagination to invent ways to keep material from washing off an urban surface into water areas.

The one option I feel is very interesting is the density, because if we increase the density, we improve the water quality. This leads to Planned Urban Devleopments, parks, and cluster developments. All the things that planners are excited about today seem to fit into water quality enhancement in these areawide studies.

Changing the point-source load indicates that going to advanced waste treatment has relatively-low impact. This is something that seems to be pretty-well known.

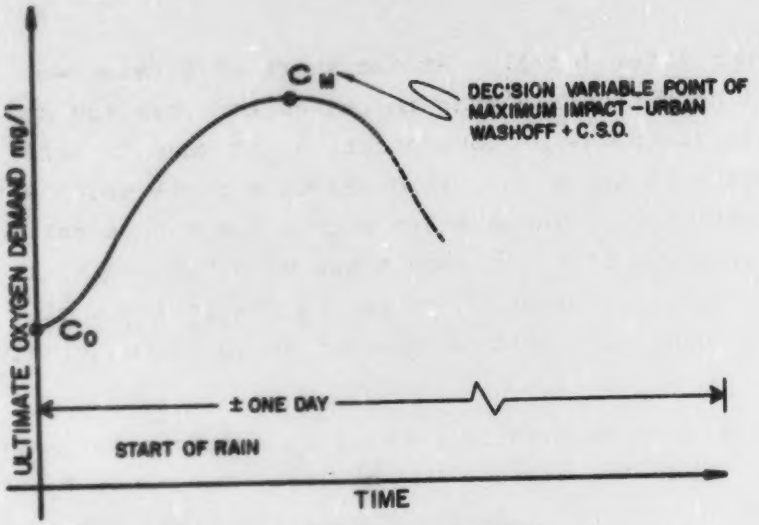
Pollutograph Control Model.

If I can digress, I have been discussing a model that handles the average water quality in the water adjacent to an urban area. I have also used a very similar analysis[3] and looked at the effects of controlling storm events while focusing on individual pollutographs. Without presenting the detailed mathematics, which are similar to those presented in the first part of this paper, I'll show the major components and what the sensitivities are for them.

Whereas, before we were focusing on one year's worth of pollution emissions and looking at the various non-point source spikes and averaging them, now I would like to refocus attention on an individual storm event and consider as a decision variable the point of maximum concentration of BOD. Figure 6 shows that the decision variable is the maximum UBOD concentration of the pollutograph that results from a storm event in an urban area. It is comprised both of urban washoff and combined sewer overflows. The pollutograph is expressed in terms of parts per million (ppm),

---

[3] Young, G.K., "Decision Perspectives on Urban Stormwater Pollution", J. Water Resources Research, in press, (Dec. 1975).



POLLUTOGRAPH

NEW OBJECTIVE: CONTROL C_M (MAXIMUM UBOD) RATHER THAN AVERAGE (DO) QUALITY

FACTORS: STREAMFLOW, C(STREAM), C(WASHOFF), C(SEWAGE), POPULATION, STORAGE (PRIMARY + DETENTION), FRACTION COMBINED SEWERS, POINT SOURCE REMOVAL

FIGURE 6

STORM EVENT CONTROL

or milligrams per liter (mg/l). At the start of a rain, we have an initial condition and this increases to a maximum and then decreases. Since this isa concentration, it doesn't tell you how much waste is going in. It could be a small storm with a high concentration or a large storm with a low concentration. There is some evidence that for some types of urban areas, it doesn't matter what type of storm it is (as long as it is of sufficient magnitude), the maximum concentration is relatively constant.

Our new objective here is to control C_M which is the maximum UBOD, rather than the average DO quality. The major factors entering into this include: the ambient stream flow; the quality of the water in the stream; the quality of the urban washoff itself; the quality of the sewage; the population; the storage that is inherent in the sewer system in terms of the primary sedimentation tanks, plus any stormwater detention tanks that may exist; the fraction of combined sewers; and, possibly, the point-source removal efficiencies.

With this simplified system, I have also calculated the relative impacts, or elasticities for a typical city that has 70% combined sewers, secondary sewage treatments, and primary treatment or its equivalent in terms of detention tanks, or three times the dry weather flow. Table 3 shows the pollutograph control relative impacts.

If we increase the stream flow, or assimilative capacity, 10%, we can increase this maximum UBOD 6.1%. This was a major policy variable (increasing the stream flow) in the early 1960's when dilution was an acceptable solution for pollution. Now, although dilution storage is called for in some existing Corps of Engineers reservoirs, it is not actively pursued as a policy option.

By means of detention or swirl concentrators, if we increase the effective storage capacity 10%, we change the maximum UBOD 1.9%. This a little misleading because we are starting from a fairly small amount of storage in existing systems. The amount of

TYPICAL CITY: 70% Combined Sewers
Secondary Sewage Treatment
Primary Treat (or eq.) for 3 X DWF

PARAMETER	CHANGE IN PARAMETER	CHANGE IN MAXIMUM UBOD
STREAMFLOW (WATER AREA)	+10%	-6.1%
DETENTION STORAGE	+10%	-1.9%
FRACTION COMBINED SEWERS	-10%	-1.3%
TREATMENT EFFICIENCY (SEC AWT)	+10%	-1.3%

POLLUTOGRAPH CONTROL

TABLE 3

storage involved in primary treatment or its equivalent that provides several hours detention, or handles three times the dry weather flow, is not a large storage volume. A 10% increase does not increase storage much. In other words, the 1.9% impact associated with storage is relatively small, but it is economically possible to increase storage several hundred percent.

Changing the fraction of combined sewers 10% decreases the load 1.3%.

Improving the efficiency from secondary toward advanced waste treatment of 10%, decreases the maximum UBOD 1.3%.

To get a comparison, for the DO model (first presented) we changed the water area 10% and got a 7.6% change in DO. Once again, we see the major effect of improving the assimilative capacity of the system.

Table 3 deals with changes in maximums. Table 2 deals with changes in averages. One point is that, when we are working with averages, we can achieve greater changes through controls than for equivalent controls when we are working in terms of a maximum. This is a very sensitive point and it bears on the fact that we really don't have an objective. Are we trying to look at the worst condition, or a certain probability level, or what have you? These analyses seem to indicate major differences in the averaging interval that is used for protection of our environment.

Conclusions.

Going back through the list of factors influencing average water quality, population is the most important; water area is next, followed by control of non-point source loading, density, and point source loading. The two top policy areas are non-point source loading and density, because we seem to be beyond the point of changing the population or increasing the assimilative capacity. Thus, we are basically looking at urban housekeeping (or the manipulation of non-point source loads) and density as two more-or-less equivalent factors.

Moreover, I would like to say that the control of environmental quality seems to be suffering from lack of a concrete objective. This analysis, and any other analysis, tends to point that out. Are we striving to eliminate non-point source loadings? Are we striving to improve average quality? Are we striving just to look at pollutographs and their effects? Just what are we striving to do and what is the objective? I think each area-wide waste management project should focus on objectives at the beginning.

Questions and Answers

Question: In the last term of the waste generation function, what was the variable?

Answer: The variable was L_p, the per capita loading rate.

Question: When you increased the density in that equation, did you hold all the other factors constant?

Answer: Yes.

Question: Would there not be some kind of compensating effect? If you increased density, you would probably increase your non-point source load because you have probably increased the built-up area in the already developed area, and therefore, you have much more runoff.

Answer: The answer is "of course" there is going to be an interactive effect that is neglected in that first order equation. However, I think the trend is there. You can increase the density in planning new towns, or by looking at undeveloped land in terms of planning for its development; if you can concentrate people and use the types of development that are in vogue now, you will improve the water quality.

Question: What is the upper end on increasing density with regard to controlling pollution or improving water quality?

Answer: I don't know. I think that Manhattan is beyond it, to my way of thinking.

Question: The type of change proposed in an increase of about 10%. That's all right for single family housing. I was wondering why the diminishing returns set in. Is the curve beginning to drop down after a decreasing density of 15% to 20% or do we reach some ultimate increase in density associated with water pollution control?

Answer: I don't know the answer to your question; but I can guess that there must be some point of diminishing returns. But this type of method and analysis would lend itself toward taking an existing situation and calibrating the situation and looking at what changes in these various directions can accomplish. As you take major steps, you have to redefine the model or determine what the correlation between variables is. You have to go to a higher order of analysis.

Question: (Ron Peterson): Other than in the DO saturation figure, is there any other effect taken into account for changes in temperature, such as the percentage of the DO changing with changing temperature; e.g., thermal discharge into a stream?

Answer: That effect is not considered in this simple model; but it certainly could be in fairly simple approaches to this problem.

Question: As a modeler, I think you are aware that most of the modeled systems can be parameterized, or subject to parametric analysis such as you have done. In fact, you can recreate the model's transfer function to account for the second order effects that have been mentioned in the discussion. In fact, some proposals like this have been advanced for environmental management information systems. Do you perceive more work being needed in this area--shifting away from the more fundamental approaches where we take a water quality model and write it in a stream?

Answer: Of course.

QUESTIONS AND ANSWERS

(Following Kenneth Young's paper, "Non-point Source Impact and Urban Holding Capacity")

Comment: Your concepts are interesting and are a novel way of looking at the whole problem. But, your conclusion on density disturbs me. According to your model, you are keeping population and land area constant. Therefore, density would be constant and your conclusion showing change in density for decreasing pollution may well be an artifact in the way you defined several of the variables. Concentrating pollutants could be one major source that would do much more damage than a series of small sources.

Young: The densification is something that is being given serious consideration. It is certainly consistent with transportation planning which is going toward density as a means of energy conservation. I'll stand pat on the model.

Question: In your example, you said 71.5% of the total load was due to non-point sources and you told us that it had been included in this model.

Young: This was oxygen demand, and it would include all washoff from the surface of the land, whether or not it got into the combined sewer. The point source was all domestic waste. That portion of the combined sewer overflow where the pollutants came from the land surface would apply in the model, and that portion of the sanitary sewers that overflowed would be a violation of the assumptions for the model. For developed land, there is about three times as much, on an annual average, from non-point sources from storm events as there is from treated point source discharges. That average is taken over a time period that includes all storm events and the dry weather intervals.

Question: I believe that this type of modeling simulates a steady-state type of modeling for decision-making. I believe most 208 Agencies are going in this direction just for convenience. My main concern with this is basing decisions on impacts that probably aren't occurring in-stream. We are basing decisions on average results of instant impacted DO.

Young: I couldn't agree with you more! My paper was based on a two-day thinking process; and, perhaps, $ 150 million would add some flesh to it.

Comment (Driscoll): When we get down to a detailed analysis, we need something more elaborate. But, the value of that particular analysis permits new approaches and concepts and gives a perspective of the problem and how all the pieces fit together. It is possible to start out with an approach that involves assumptions.

QUESTIONS AND ANSWERS

(Following G. K. Young's paper "NPS Impact and Urban Holding Capacity

Question: In the last term of the waste generation function, what was the variable?

Young: The variable was L_p, the per capita loading rate.

Question: When you increased the density in that equation, did you hold all the other factors constant?

Young: Yes.

Question: Would there not be some kind of compensating effect? If you increased density, you would probably increase your non-point source load because you have probably increased the built-up area in the already developed area, and therefore, you have much more runoff.

Young: The answer is--"of course". There is going to be an interactive effect that is neglected in that first order equation. However, I think the trend is there. You can increase the density in planning new towns, or looking at undeveloped land in terms of planning for its development. If you can concentrate and use the types of development that are in vogue now, you will improve the water quality.

Question: What is the upper end on increasing density with regard to controlling pollution or improving water quality?

Young: I don't know. I think that Manhattan is beyond it. For me, it is.

Question: The type of change proposed is an increase in density of about 10%. That's all right for single family housing. I was wondering why the diminishing returns set in. Is the curve beginning to drop down after an increase in density associated with water pollution control?

Young: I don't know the answer to your question; but I can guess that there must be some point of diminishing returns. But this type of method and analysis would lend itself toward taking an existing situation and calibrating the situation and looking at what changes in these various directions can accomplish. As you take major steps, you have to redefine the model or determine what the correlation between variables is. You have to go to a higher order of analysis.

Question (Ron Peterson): Other than in the DO saturation figure, is there any other affect taken into account for changes in temperature, such as the percentage of the DO changing with changing temperature; e.g., thermal discharge into a stream?

Young: That effect is not considered in this simple model; but it certainly could be in fairly simple approaches to this problem.

Question: As a modeler, I think you are aware that most of the modeled systems can be parameterized, or subject to parametric analysis such as you have done. In fact, you can recreate the model's transfer function to account for the second order effects that have been mentioned in the discussion. In fact, some proposals like this have been advanced for environmental management information systems. Do you perceive more work being needed in this area--shifting away from the more fundamental approaches where we take a water quality model and write it in a stream?

Young: Of course.

RUNOFF AND QUALITY

E. D. Driscoll - Hydroscience

INSTREAM IMPACTS FROM STORM OVERFLOWS

Water quality changes in receiving waters are caused by contaminant loads, i.e. by the total pounds of a pollutant which enters the natural water because of a storm overflow. There is a growing body of data identifying storm generated contaminated loads expressed as areal loading factors, for example pounds per acre per year. Data of this form is useful, and this approach to identifying loads is necessary for those areas where loads enter the receiving water in a very diffused manner. Upstream sections of a drainage basin, or un-sewered areas would require this approach. Such data is also useful in comparing data from different locations, or for considering the effect of those contaminants which have a large time and space scale associated with their instream impact.

For urban settings, however, where storm runoff is collected and conveyed to the receiving water through a sewer system, where structural control measures are to be considered and where the transient nature of receiving water impacts must be defined - identification of storm loads in this manner lacks adequate definition and detail.

In such situations, storm generated contaminant loads are best characterized by product of runoff flow and contaminant concentration. This approach to waste load definition best accounts for the transient nature of the loads, and the variability from event to event. It provides the type of data base required to evaluate structural solutions, as well as some non-structural ones.

It then becomes necessary to appropriately characterize runoff flows and quality for a specific area.

RUNOFF

Stormwater runoff is generated by the rainfall on an area. The rain water flows across the surface and gravitates toward the natural outlet from the area either through natural drainage courses or through sewers or other collection systems. The amount of runoff is related to the quantity of rain. Not all rain striking the surface will reach the outlet of the drainage area. Some percolates into the ground or is retained in natural depressions. The net result is that only a fraction of the rain falling on an area will ultimately show up as runoff.

This fraction may be quite large, or quite small, and is in fact extremely variable. A predominant influence on the fraction of rainfall which runs off is the degree of impreviousness of the area. The major effect is due to artificial surface cover such as pavement, roof tops, sidewalks, and the like. Soil types in the other areas also exert an influence. Secondary effects, such as ground slopes, soil moisture, and the like introduce further modifications.

The amount of runoff generated by rainfall is therefore very sensitive to local conditions. It is also subject to variation based on specific characteristics of the storm which generates it - for example, the intensity, the time since the antecedent storm, etc.

Regardless of the significant effect of these factors, it is well to bear in mind that the predominant influence on the amount of runoff to be expected at any particular time, is the rainfall process itself. Figure 1 provides some perspective on the relationship between storm flows and normal sewage flows for an urban area. It also illustrates the tremendous range in storm flows which can be generated based on the particular storm characteristics.

The rainfall process itself is extremely variable, and the approach therefore taken to characterize runoff, has been to develop it as a proportional relationship to the rainfall itself. A convenient approach is to define the ratio between the amount of rain falling on an area, and the amount which runs off

$$C = \frac{V\ \text{runoff}}{V\ \text{rain}}$$

There have been refinements to this approach, some of which are used in current storm water models. The simple ratio however, because of its simplicity and familiarity remains a useful basis for exploration of stormwater problems. This is certainly the case for this discussion, and at this point it appears that it will prove to be the most effect basis for analyzing most problems associated with stormwater overflow, at the planning level.

SEWAGE FLOW

(100 GCD)

POPULATION DENSITY	10	20	30	40
AVERAGE DWF GAL./HOUR	42	84	125	170

STORM RUNOFF

(C=0.5)

RAINFALL INCH/HOUR	0.015	0.15	1.5
RUNOFF GAL./HOUR	200	2,000	20,000

FIGURE 1

COMPARISON OF STORM AND SEWAGE FLOWS FOR ONE ACRE AREA

In the following discussion of factors which influence runoff, we will be concentrating on the runoff coefficient, c. It represents the ratio of the volume of stormwater applied to the area as rainfall, to the volume of stormwater leaving a drainage area.

Figure 2 summarizes and condenses some published data. It illustrates the very substantial effect on runoff due to land use. The effect of increasing population density over the spectrum of urban development from rural through industrial and commercial development, is primarily a reflection of the extent to which natural land surfaces are covered by impervious surfaces (pavement, etc.). The actual value in any area can vary from the overall mean value for the equivalent population density, by 25 or 30%. This appears due in substantial part to the soil characteristics and topography of the local area or the degree of industrial or commercial development.

The relationship shown here illustrates the magnitude of the effects that increasing urban development can have on the storm runoff problem. Urban development substantially increases the amount of rainfall which reaches receiving waters quickly. The figures summarized by this plot represent broad average values based on data throughout the country. The land use characteristics of a particular area will thus define in a relatively broad sense the order of the runoff coefficient.

There are however other factors which modify it. Figure 3 illustrates in a relatively simple manner the effect that the rainfall process itself can have on the amount of runoff generated. The curves shown are taken from a

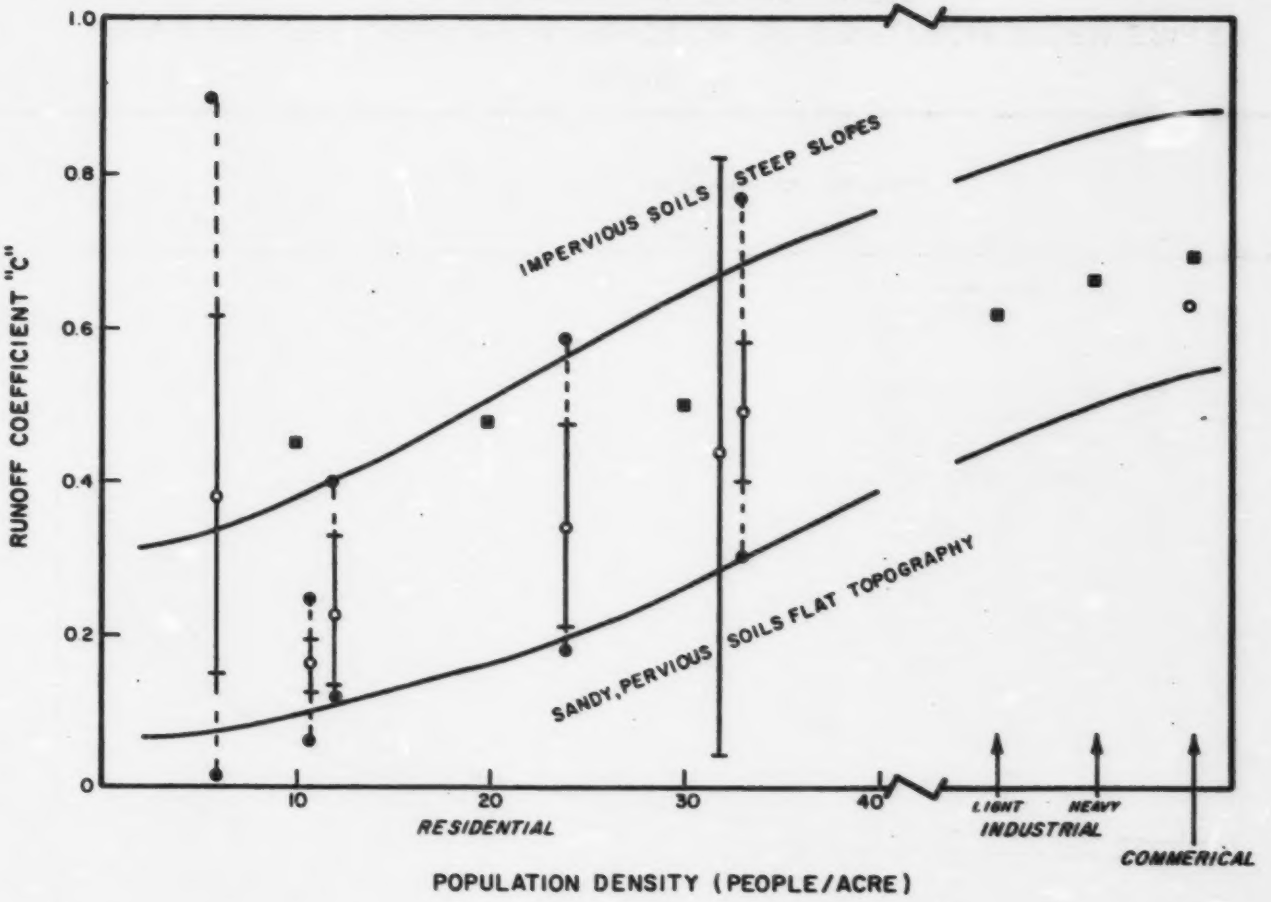


FIGURE 2
LAND USE VS RUNOFF

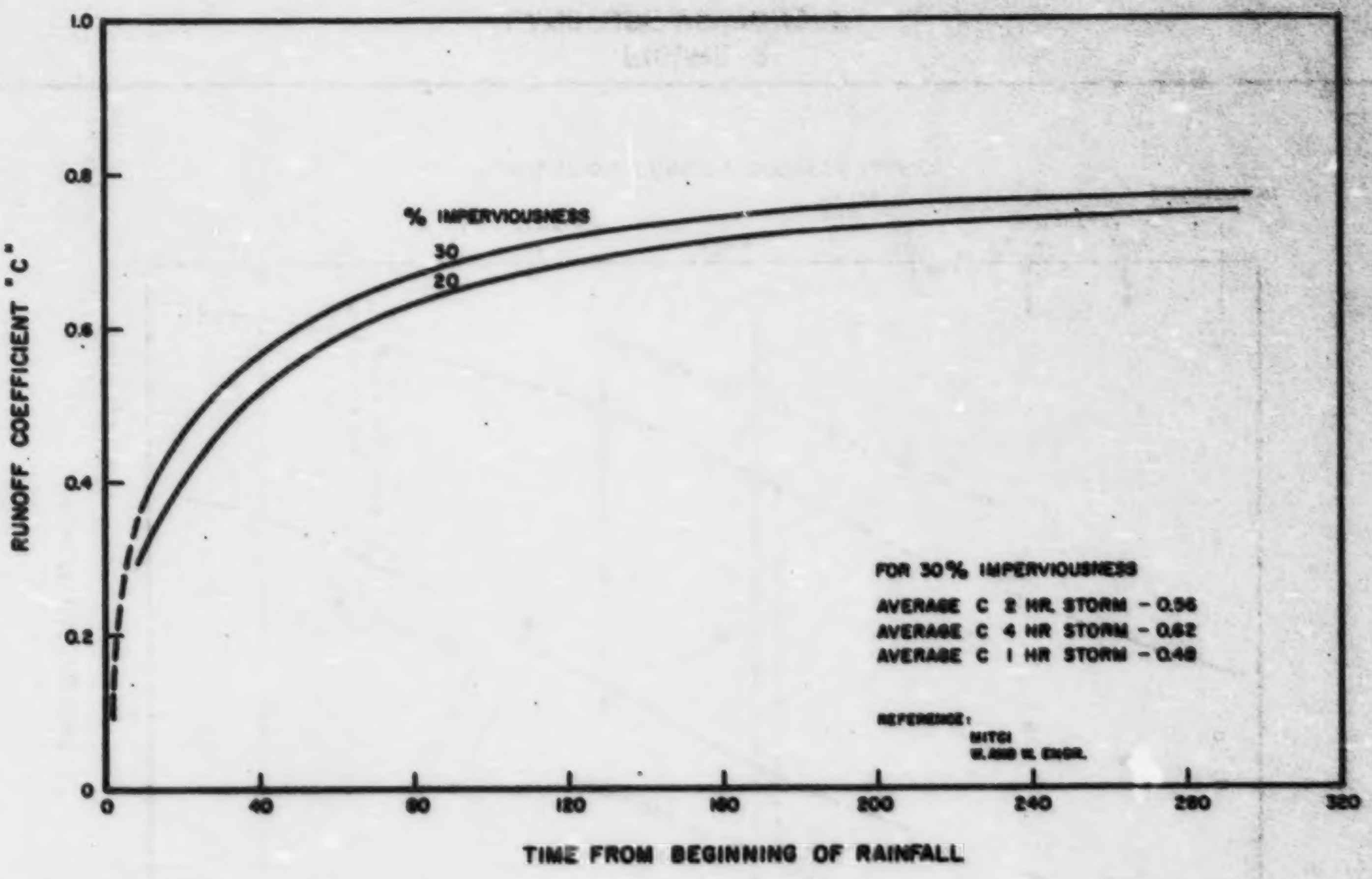


FIGURE 3

RUNOFF COEFFICIENT AS A FUNCTION OF TIME FROM STORM START AND PERCENT IMPERVIOUSNESS published report describing for a particular area the change which the runoff coefficient undergoes as a storm progresses. For any particular degree of imperviousness (we show 20% and 30%) the runoff coefficient increases as the storm progresses due to the effect of continuing rainfall on depression storage and on infiltration rate. What is interesting is a calculation based on this data which shows that for this basin with 30% imperviousness, the average runoff coefficient (c) for a 2-hour storm is 0.56, whereas for a 4-hour storm it has increased only to 0.62. Other than for very short storms, the variation in runoff coefficient due to changes in infiltration and depression storage during the course of a storm may be only in the order of 10 or 15%.

Another, and quite significant factor influencing the runoff coefficient relates to the measurement of rainfall itself. Consider Figure 4: the data comes from two published studies, one for Milwaukee, Wisconsin and one for Durham, North Carolina. Each provided a substantial amount of data on individual storms in which both the rainfall was recorded, and the runoff was measured. Note the substantial spread in the value of the runoff coefficient for each area when the data is analyzed statistically. Milwaukee had a higher median runoff coefficient (0.45) compared with Durham (0.35), as might be expected from differing land use patterns. There is however a substantial spread in observed coefficients for each location - well beyond the 10 to 30% differences noted in the previous graphs. These data are for a specific area, in which nothing changed during the course of the study other than the rainfall. The degree of

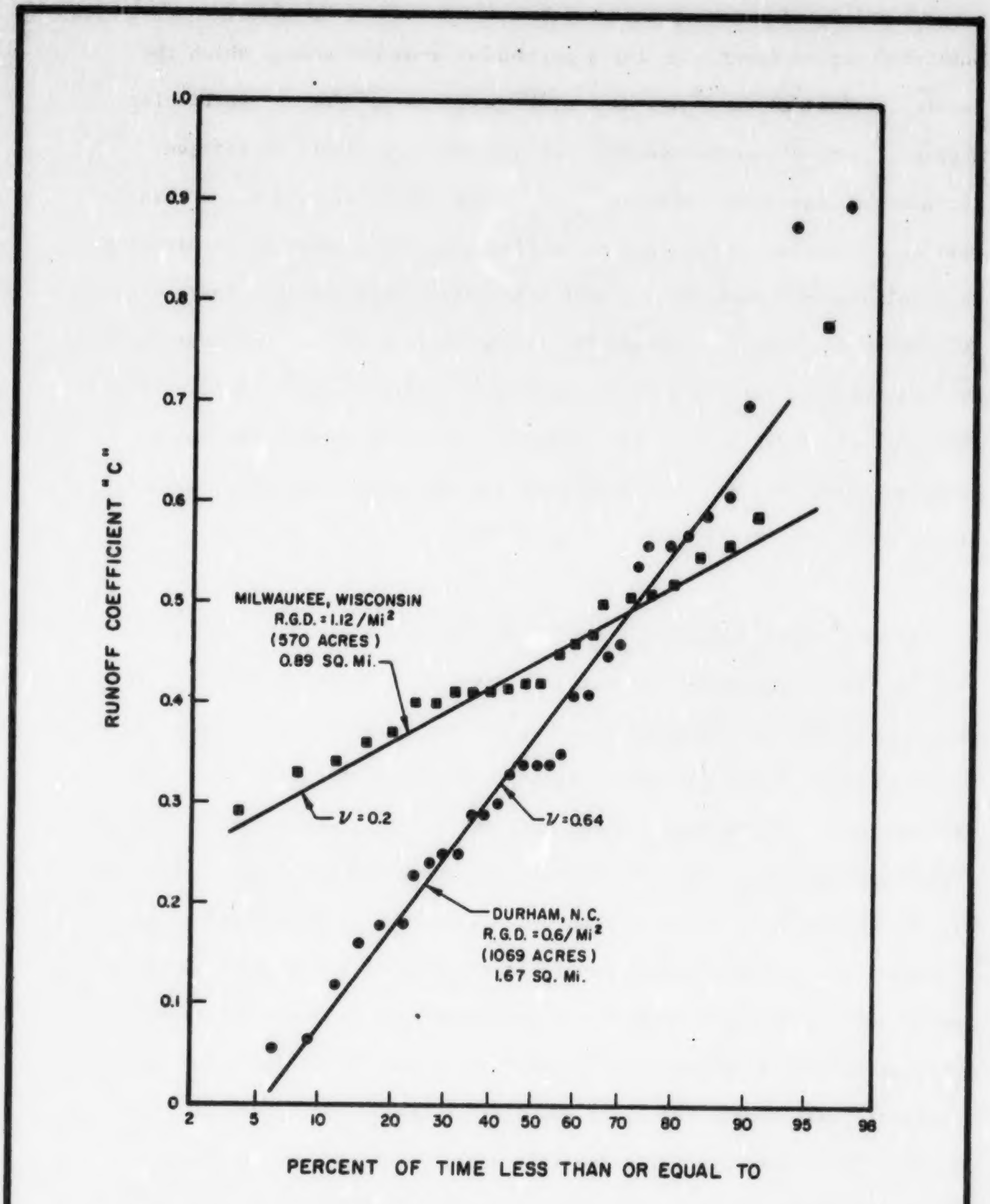


FIGURE 4
STATISTICAL VARIATION IN RUNOFF COEFFICIENT

variability is due largely to rain gage density rather than to the factors we have discussed until now.

The effect is substantial, and it is significant. It is due to the fact that our perception of the rainfall on an area is determined by what is measured at a particular rain gage or set of gages. The variation in the statistical plot is a reflection of the degree to which the rainfall intensity measured by the rain gage differs from the average intensity over the entire drainage area which the gage in question is assumed to represent.

Figure 5 illustrates this point schematically. Rainfall is not distributed uniformly over an area. Any rain gage at a specific location in this area will therefore either over-estimate, or under-estimate the average rainfall over the entire area, which is what ultimately determines the amount of runoff which leaves the area. The larger the drainage area served by the gage, (that is the lower the rain gage density), the less likely it is the gage reading will represent the average rainfall. This will increase the variability of the data, as is in fact illustrated by Figure 4.

> The significance of this is the following:
> The runoff calculated from rainfall, as measured by a rain gage will not have a consistent relationship. Any particular rainfall recorded by a gage will correspond not to a particular runoff value, but to a range of possible runoff values. The greater the rain gage density, the narrower the probability limits on runoff will be.

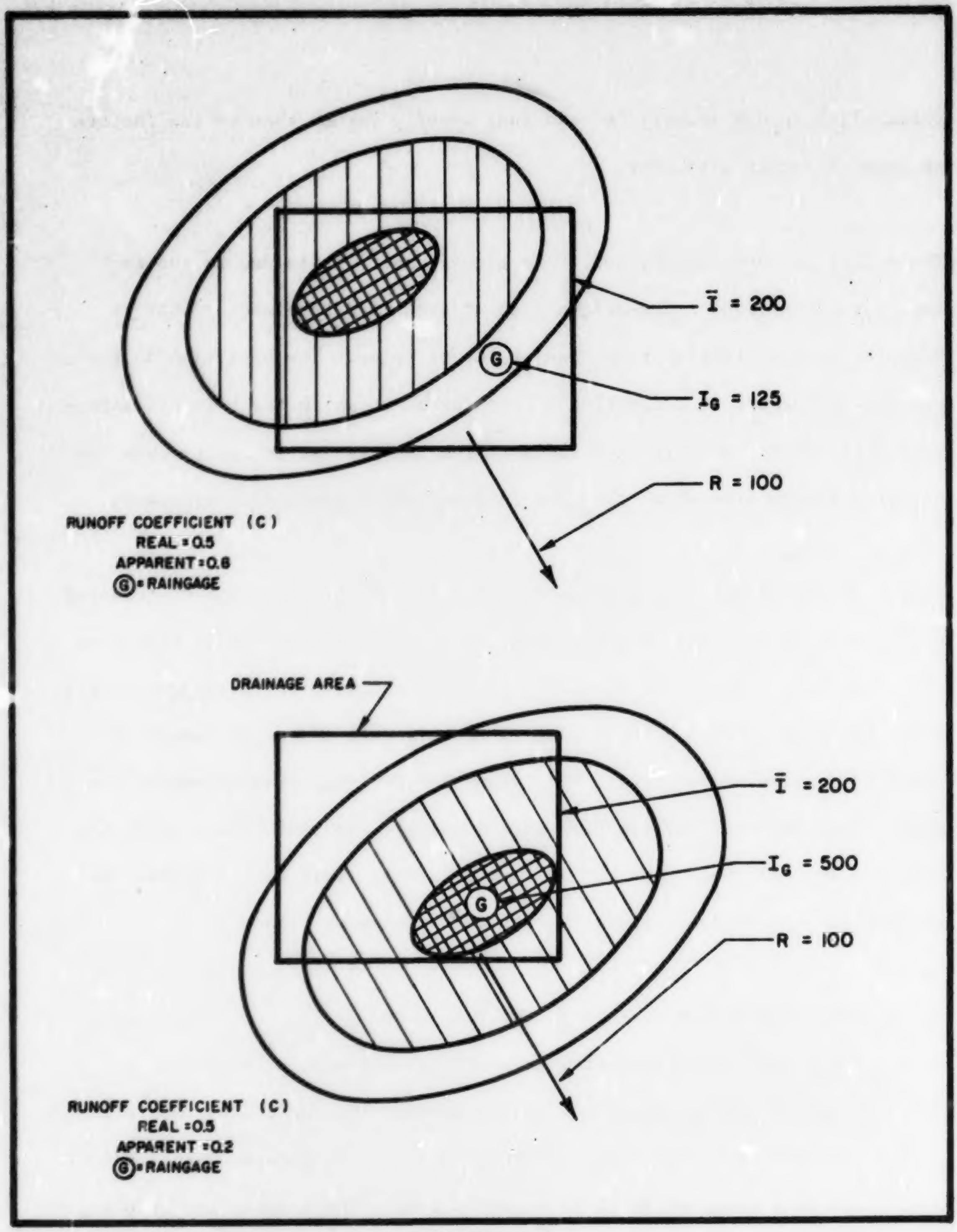

Ī = 200
I_G = 125
R = 100
RUNOFF COEFFICIENT (C)
REAL = 0.5
APPARENT = 0.8
Ⓖ = RAINGAGE
G
DRAINAGE AREA
Ī = 200
I_G = 500
R = 100
RUNOFF COEFFICIENT (C)
REAL = 0.5
APPARENT = 0.2
Ⓖ = RAINGAGE
G

FIGURE 5
EFFECT OF AREAL DISTRIBUTION OF RAINFALL
ON REAL VS. APPARENT RUNOFF COEFFICIENT

Since the variation in runoff due to the limitations in our measurement of rainfall may be broad, we must examine the significance of any refinements in calculations to account for other effects which have a much smaller influence on the runoff calculations. We should further examine the usefulness of considering arbitrary individual events. We must also keep these factors in mind when establishing a monitoring program or interpreting data from such a program.

Figure 6 illustrates schematically how our ability to identify "real" effects of storm properties, land use, etc. may be masked by variations introduced by a low density of rain gages. A measure of the variability of a set of such data, is provided by the coefficient of variation (V), defined as the ratio of the standard deviation to the mean.

$V = 1.0$ or more indicates extremely variable data - for example

1 standard deviation $= \pm 0.5$

$$V = \frac{0.5}{0.5} = 1.0$$

thus range of $C = 0 \longrightarrow 1.0$

$V = 0.1$ and mean $C = 0.5$

1 standard deviation then is ± 0.05

thus range $C = 0.45$ to 0.55

(Above ranges for a standard deviation)

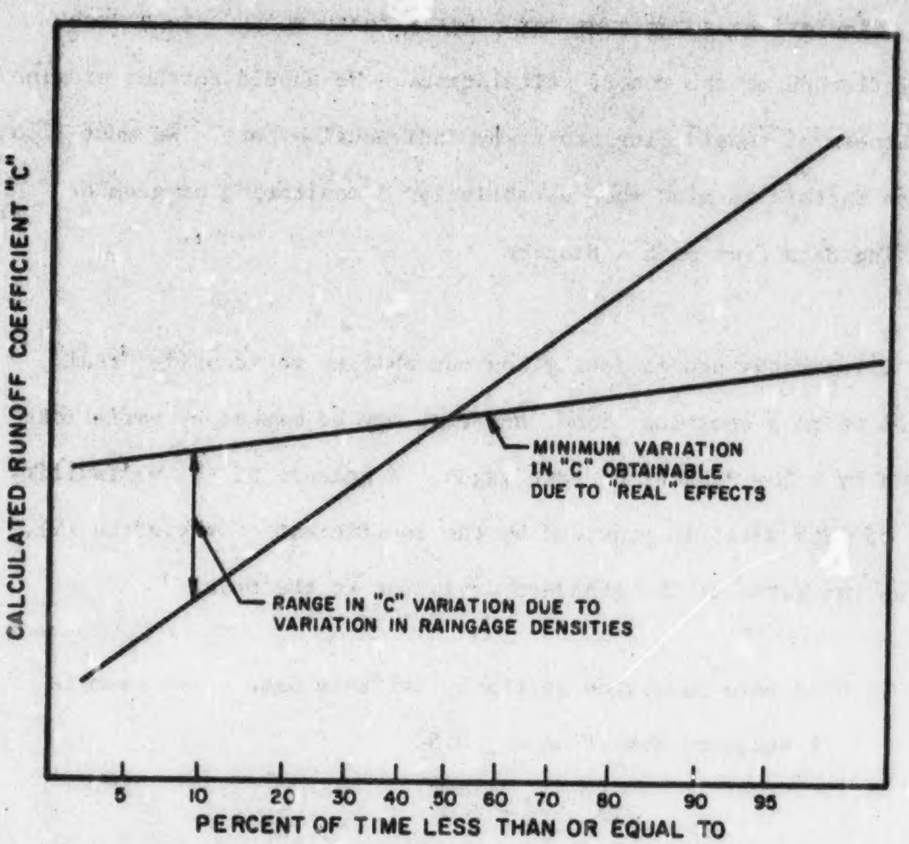


FIGURE 6
CONCEPTUALIZATION EFFECT RAINGAGE DENSITY ON RUNOFF COEFFIENT CALCULATION

Using this concept to develop a quantiative sense of the significance of rain gage density, Figure 7 has been developed. Data from a number of studies has been analyzed and plotted, along with a theoretical expression for the relationship between rain gage density and the variance of runoff coefficient. Considering that a coefficient of variance in the order of 0.1 or 0.2 would limit the standard deviation to + or - 10 to 20% of the mean, we can estimate that rain gage densities in the order of 1 to 5 gages per square mile would be desirable.

It is readily conceded that such a figure represents an excessive number of gages for the typical 208 planning area. It suggests that an effective approach would be to concentrate study effort on selected smaller areas, where suitable gage density can be provided. In situations where this is not possible, it provides a basis for understanding the variability which will be encountered, and to factor this into conclusions and decisions.

QUALITY

Contaminant concentrations in storm runoff vary considerably, under the influence of storm patterns, land use, type of constituent, time since it started raining, and conditions related to size of, and time since the antecedent storm event.

The predominant influences are land use patterns, and whether the storm drainage system consists of combined versus separate sewers.

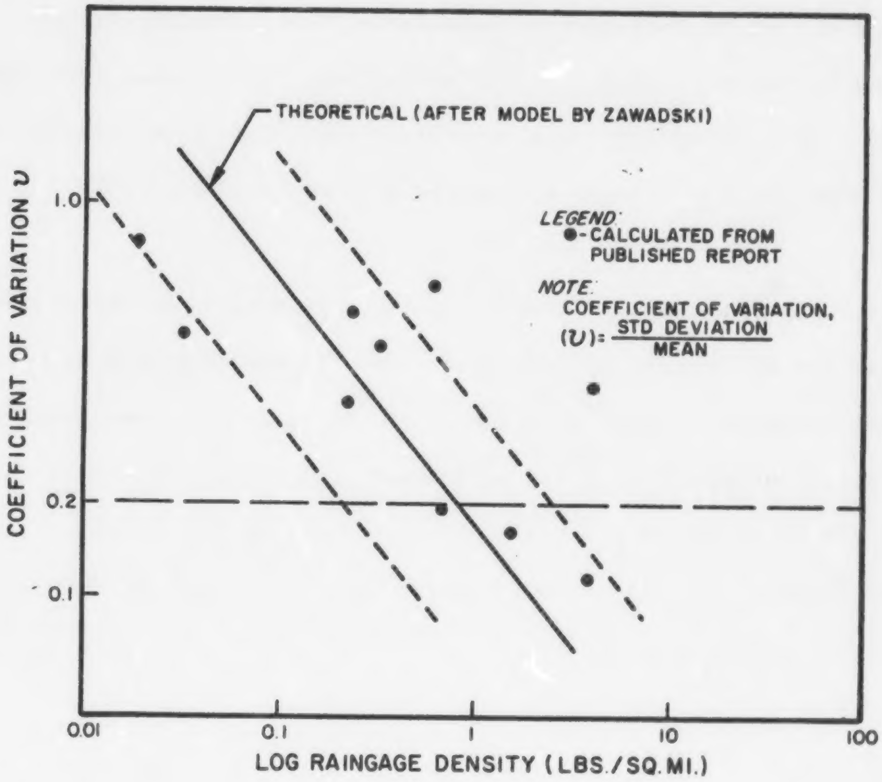


FIGURE 7
RAINGAGE DENSITY VS.
VARIABILITY OF MEASURED RUNOFF COEFFICIENT

Of the secondary influences, the variation due to time since the start of rainfall (or runoff) is important. The early stages of storm runoff carry proportionately higher concentrations of most contaminants than later runoff, due to first flush effects. Initial runoff flows flush accumulated debris from catch basins, streets, land surfaces and sewer lines - and result, on the average, in higher waste concentrations during the initial runoff period. This relationship can be important because of the influence it may have on a number of control approaches.

The magnitude of the first flush effect, and its significance may vary significantly, depending on whether combined or separate sewers are in use, and the size of the drainage area. Large areas, with significant times of concentration may cause a masking or damping of first flush effects as they reach the sampling station in a staggered fashion.

For combined sewers, the effect may be less pronounced than with separate sewers, because storm flushes will be "diluted" by the high contaminant levels in raw sewage. Data on combined sewer overflows from 97 storms at Milwaukee, Wisconsin are summarized by Table I. Although any random, individual event may not clearly reflect the first flush effect, the net effect when all events are considered is storm generated concentrations of BOD, solids, COD, chlorides, Organic Nitrogen and Nitrate, in the early states of runoff are 1.5 to 2.5 times dry weather concentrations in sewage. For some contaminants (Ammonia, Phosphorus, Fecal Coliforms), storm generated concentrations are lower - indicating the predominant source to be the raw sewage.

TABLE 1

COMPARISON DRY AND WET WEATHER SEWAGE QUALITY

	Dry Weather Quality		Wet Weather Quality			Ratio
Parameter	Average Concentration	Range	Initial Value	Maximum Value	+ 2 Hour Value	Max DW Avg
BOD (mg/l)	112	17-323 *	150	176	87	1.57
SS (mg/l)	150	5-900 *	397	489	193	2.63
TVS (SS)(mg/l)	115	2-700 *	242	289	106	2.51
pH	7.6	6.7-8.7	6.9	7.1	6.9	
COD (mg/l)	238	35-730 *	439	581	256	2.44
Cl (mg/l)	141	3-826 *	188	210	117	1.5
TKN (mg/l-N)	20.7	5.6-47 o	14.6	17.2	8.6	0.83
Organic (mg/l-N)	9.0	4.6-16 *	10.0	11.5	5.3	1.28
NH_3 (mg/l-N)	11.7	1.0-31.2 o	4.6	5.7	3.3	0.49
NO_2 (mg/l-N)	0.01		0.01	0.01	0.01	-
NO_3 (mg/l-N)	0.5	0.1-1.6 *	0.83	1.01	0.63	2.0
Ortho-P(mg/lPO_4)	10.7	1-39 o	7.8	9.4	4.9	0.88
Total-P(mg/lPO_4)	18.4	0.5-60 o	13.4	15.7	8.4	0.85
T Col (nu/ml)	930,000					
F Col (nu/ml)	38,000	400-54000 o	14,000	22,000	6,200	0.58

*Initial Wet greater than average dry.
oInitial Wet less than average dry.

Some typical data from separate sewers is illustrated by Figure 8 for an urban area, and Figure 9 for a semi urban - rural area. Note that when concentrations are considered, a first flush effect is definitely indicated for all cases, with the exception of BOD in the runoff from the rural area.

An important factor illustrated by these plots, is the time variation of the Mass emissions of BOD and suspended solids Mass emission (i.e. #/hr) as distinct from concentration, follows a pattern which is dominated by runoff flow.

DATA NEEDS

Considering the variable nature of the process generating storm overflow loads, and the variability indicated by data from storm water studies, it should be clear that some local assessment of storm loads is necessary to compare with information on the process developed from previous studies. Information on rain gage density, on flows and quality of runoff or overflows is required to identify the significance of local effects.

Problem analysis and the assessment of alternatives, also requires that pertinent physical data be assembled. This would include the capacity and routing of Interceptor lines, location of overflow points, and the identification of any constraints on potential locations of structural control devices.

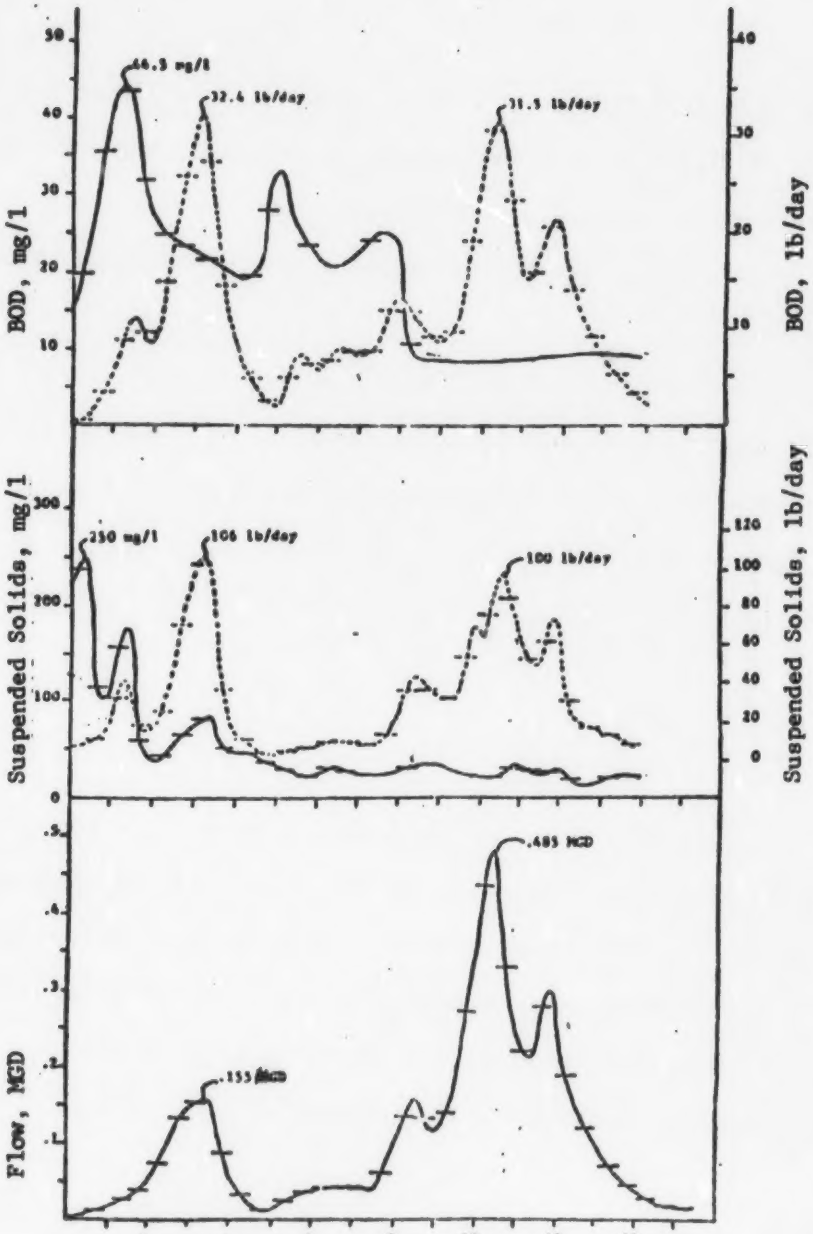


FIGURE 8. Variation of Flow, BOD, and Suspended Solids During the Storm of Nov. 13, 1972 at the Urban Sampling Station.

Source: Stormwater Runoff Quality for Urban and Semi-urban/Rural Watersheds, by F. T. R. Mc Elroy III and J. M. Bell, February 1974, Purdue University Water Resources Research Center.

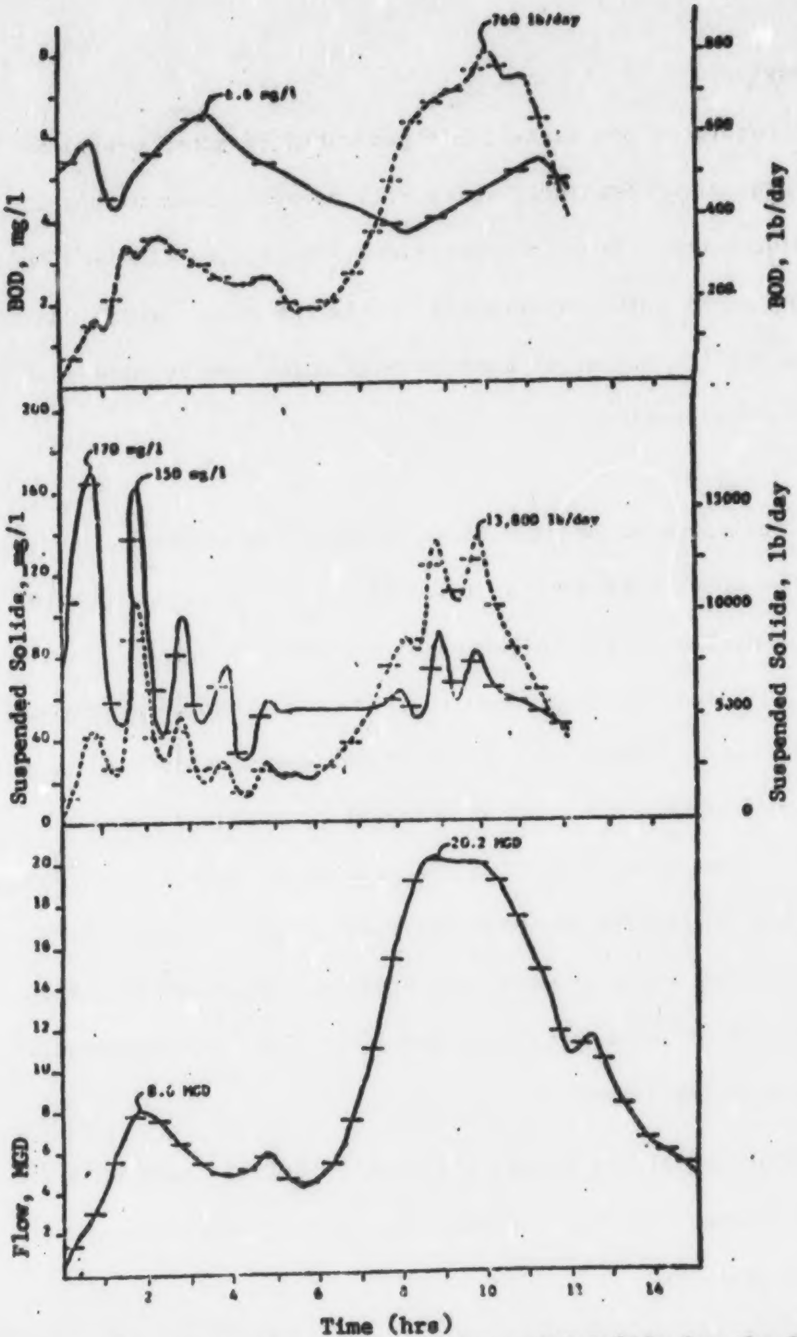


FIGURE 9. Variation in Flow, BOD, and Suspended Solids for the Storm of Nov. 13, 1972 at the Semi-Urban/Rural Sampling Station.

Source: Stormwater Runoff Quality for Urban and Semi-urban/Rural Watersheds, by F. T. R. Mc Elroy III and J. M. Bell, February 1974, Purdue University Water Resources Research Center.

PROGRAM CONSTRAINTS

The variable nature of the waste loads generated by storm overflows implies a degree of uncertaintly which will be associated with a limited numer of measurements. Program constraints - available time and budget for addressing storm water aspects will limit the effort which can be made - i.e. limit the number of measurements which can be made - at least for the initial evaluation.

An effective analysis can be made if we recognize these facts, and adopt a program which balances the level of detail employed in both monitoring and problem analysis phases of the study program. This means that we plan the planning study such that we do not adopt for any one aspect of the study, a level of refinement and detail which is incompatible with levels obtained for other integral components.

> Example - waste loads will be the product of Flow X Concentration. It is not meaningful to determine flow variations very precisely if concentrations are known only crudely. At a design level, flows may need to be known with more precision - but not necessarily at the planning level.

Further, the planning effort should not seek to define loads with greater detail and refinement than are necessary to identify significant effect on receiving water quality.

PROGRAM GUIDELINES

RATIONALE - 208 Planning studies operate within a specific budget and time frame (about 12 to 18 months for technical analysis). The randomness of the storm overflow process argues that enough "general" data will probably not be secured within this time frame to "average out the variations," to put it simply. It is enough time to identify the key influences, however, if the effort is focused properly.

1. Select several small areas for detailed analysis, rather than attempt a broad assessment for a large area. With a good handle on how specific type areas will behave under storm influences, one can then synthesize the combined response of a large area.

   Small study areas should be selected to include the range of land use or population density conditions in the area, preferably such that each area selected has one such pattern which predominates.

2. With a limited number of small areas being studied in detail, we can afford to eliminate much of the variability due to rain gage density, by placing an appropriate number of gages in each area.

   This becomes esepcially important in areas with significant changes topography that influence rainfall.

3. Locate flow measurement and sampling stations at a common point, at the outlet of each study area.

4. Obtain data on as many storm events as practical within overall program constraints, but probably not less than about a dozen events.

   Select sampling and analysis interval on the basis of an analysis of system responses in the receiving water. In most cases, will not have to consider anything less than 1/2 hour or 1 hour composites for analysis - in some cases, longer composites may be appropriate. Composites should be flow weighted, and care should be taken that even short storms are picked up

   If necessary, concentrate analysis on those contaminants which influence the receiving water problem you are trying to relieve.

CONCLUSIONS

Local determination of Runoff and Quality should be made.

Expect variability in data; select program such that you maximize ability to relate variations to local causes.

Rain gage spacing (density) can introduce variations substantially greater than those caused by storm or surface effects.

Adopt a level of detail consistent with the sensitivity of other elements in the analysis to the level of detail of the inputs.

QUESTIONS AND ANSWERS

(Following Mr. Driscoll's paper, "Runoff and Quality")

Question (In reference to a slide shown by Mr. Driscoll): Doesn't that essentially refute the "first-flush" effect?

Driscoll: No. It actually refines it somewhat. The first-flush effect is significant in pollutant concentration. The flow itself has such a tremendous influence on the pounds of pollutant that it can totally distort the first-flush effect from one rainfall to another because the rain can occur in almost any pattern.

Question (Dan Goodwin, Illinois): If there is a first flush evident from the combined sewers in the Chicago area, it lasts more than 15 hours. Do you have any comment?

Driscoll: That is a long time for a first flush.

Condon: May I add one thing to what you said? All you said is correct. But, there is one more variable. This is the peculiarities of the collection-transport system. With long, flat slopes there is more opportunity for deposition in the system. Chicago is an example, and it can have a long first flush because the system is picking up from all over the District's widespread system.

Question: What is the correlation coefficient that you think we should know?

Driscoll: From a limited amount of data, a correlation coefficient for rain gage densities of 4 gages per square mile is .87 which removes about 75% of the variability of measurements.

Question: In a combined sewer system, I assume that there would be a lot more of the total pollutant loading in the first flush. Is that safe to assume?

Driscoll: No, not necessarily. Some data that I analyzed from a Milwaukee combined sewer system showed that there was a first flush if one looks at concentrations. In the first flush, extra material is picked up at the first stages of the storm. If you look at pounds, though, the flow variation, where high flows come later in the storm, so overwhelm the picture that the effect is totally masked.

Question: It has been argued that the first 0.25" of rainfall will pick up about 90% of the BOD from a combined system. There, obviously, is some conflict between sources of information.

Driscoll: I don't recall seeing any data that could support that as a general statement.

Condon: That "first flush" thing is beated to death! It is a common occurrence; but, because it is common, people like to consider it a truism for all storm events. There are reports that show, for a given system, that sometimes first flush occurs and sometimes it doesn't. A report by Rex Chainbelt Company for Milwaukee illustrates this and effects of antecedent events and the orientation of a storm path to the collection system.

Question (Lumb): I have a few comments on the Rational Formula Coefficient that you discussed. I noticed that when you showed data for Durham, N.C., you had runoff coefficients ranging from 0.1 to about 0.9. In your analysis, you decided that the variation was due mostly to the poor precipitation records or that the gaging coverage was not adequate. My experience indicates that there are several factors that determine what that runoff coefficient will be. These are the initial soil moisture condition when the rainfall starts, the duration of the rainfall, and the amount of rainfall. The latter two exhibit variations that are much greater than the variation found in precipitation coverage. It is unfortunate that hydrologists are plagued with this "runoff coefficient". It isn't very good and it has limitations. Its use has, basically, been limited to a 10-year storm, or very large storms, over small basins. Use of the Rational Method does not represent hydrology very well. In the Kansas City area, when looking at data for a 5-inch rainfall, it may be that none of the precipitation would run off or possibly 80% may run off--depending upon the antecedent conditions. If we're going to use a straight coefficient, say an average between those two, we will get gross errors in our analysis of the stormwater runoff. If we assume an average condition, our critical conditions quite often might be the summer low flows. If we use an average runoff coefficient, we may compute two or three times the runoff in our modeling as occurred in the real world. This would end up concluding that possibly we cannot do anything about stormwater runoff. I think we have to be very careful when we talk about, or use, this rational coefficient.

Driscoll: Your points are well taken and whether the relative effect of the rain gage density versus the local effects vary from area to area depends upon how much of the area is soil that can be dried out and how much is pavement. There is no substitute to gain the best handle on the effects on the local situation. I accept your comments. My generalization may have been a little poor, but we get back to the same point--that you have to use the Rational Formula with consideration and try to relate it to your local situation. I guess the other point is that there may be so much going on that the inherent limitations of this very simple approach may be appropriate for the broad-scale planning studies that we want to make. We have to look at the significance in each case.

Question (Lumb): Assuming that you have a time variability in BOD loading, how can you input this into a steady state model, such as you spoke of before, inputing an average BOD loading?

Driscoll: If you are trying to establish a time variable effect, you can't put it into a steady state model unless you do it in some steady state fashion and recognize that you are getting a steady state approximation to what may be a totally different time variable situation.

Question (Lumb): Is it justified at all, then, to use steady state analysis in this type of situation?

Driscoll: Perhaps, on a first cut, one might consider making a steady state analysis, plugging in the order of point-source loads, the order of storm loads, if they were an average, and several others such as agricultural load and what-not to get a sense of the relative significance of each source on water quality. If your storm loads are significant, it is a transient thing and you can't use a steady state analysis to identify what's going on.

Question: We had considerable discussions so far on mathematical modeling and data collection and sampling, but what do you do in an area where you have one first-order meteorological station for 1,600 square miles and, maybe, 5 farmers that collect rain gage information when they get around to it, and existing water quality information is insufficient for any type of mathematical model and is generally unrelated to storm events at all?

Driscoll: If you want to have an effective plainning program, you have to get some data.

Comment: The 208 program doesn't allow time for this.

Driscoll: You can do a good amount within that time frame.

Comment: Trying to make significant predictions on one or two years data is difficult.

Driscoll: I guess my point is that the approach you have to take is to put gages in to identify the runoff and waste land properties of the area that you can relate to rainfall. Then to do your analysis, you would never use those two years of data. You would find a weather bureau station located close by that had 30 or 40 years data and use that to define the rainfall statistics.

Comment: But you just mentioned that one station will be by-passed by a significant number of storms.

Driscoll: That's right, but it's better than trying to work with only two years of data.

Comment: I'm just wondering, under those circumstances, what advantages any sort of mathematical modeling would have. Wouldn't the general local knowledge of people familiar with the area's characteristics and waters, and purely qualitative evaluations be equally valuable, perhaps even more so?

Driscoll: That would certainly be valuable; but, to me, in a complex situation where there are water quality problems due to rainfall, point sources, etc., an evaluation like that doesn't really give you much basis for making competent judgements on specific things that you can do.

Comment: I'm comparing it though, with a one-year sampling period. For some of us who have to turn out the final plan and make initial assessments by early 1977, there really isn't much more than a year to go.

Driscoll: I would tend to look at the 208 planning process. It's going to be of value for the area. It is a step toward telling them what's the most effective way to go about achieving the water quality objectives. I would look at it as a staged approach. You answer the questions that you can answer in the two years and you set a base for following the questions that you will attempt to answer later.

Comment: This doen't exactly solve the two-year 208 problem, though.

Driscoll: So you do a two-year study! Some of your conclusions will be very fuzzy and some will be very positive. And if you draw a conclusion about rainfall and urban storm runoff with one gage in the state, you say "this is the conclusion but this is the limitation of it." Then, when somebody comes to put up money they're going to think twice about how fast they ought to pour money into that.

Comment: My point was--when you start dealing with mathematical models you have numbers, and numbers have a tendency to be precise. The general public gets an idea from this that, because you have a certain number, the number is reliable. They feel this way far more than the people working with it do. I'm just wondering how much value there is in trying to do any sort of modeling in the time constraint, in view of financial constraints and the general characteristics of the existing situation.

Driscoll: There can be significant value, I believe. I also agree with you that one must make certain that more isn't read into these calculations than is appropriate.

Question: In terms of analysis of the rain gage densities, is this purely a theoretical analysis, or have you actually looked at data on different rain gage densities?

Driscoll: We're in the process of looking at that, and what I presented was the preliminary results of that effort. We're looking at empirical data. We are hoping to extract information from all of the studies around the country and to piece it together.

Question: What is the largest rain gage density you found in practical use? What concept are you using for distribution of gages?

Driscoll: I'm not using anything. I'm looking at published data from studies that analyze the storm problem for quality and flow, and just working empirically back to what it was.

Question (Dan Goodwin): Assume you were attempting to define a design storm. Assume it is a storm beyond which, if you had a violation of water quality standards, you wouldn't worry about it. But, you'd simply write it off as something you could not cope with today or within the next 20 years. What parameters would you look at in selecting that design storm?

Driscoll: I would follow the technique we're trying to develop in a manual for EPA. There isn't any particular line that one draws. One sets up an analysis such that we can identify the frequency of violation of a standard with the cost of an alternative. You have a trade-off.

Question (Goodwin): Are you suggesting an approach other than applying "uniform" standards for an area, region, or for the country?

Driscoll: I am saying that, in each case, you must decide what standard you will require and what percent of the time it must be met.

Question (Goodwin): Do you have any thoughts on performing the modeling exercise to achieve the trade-off in storm events between intensity and total rainfall for different kinds of situations?

Driscoll: Yes, I do. The thing to do would be to analyze each of the possible storms, sequentially. Then, decide which is the worse storm. We are trying to develop an approach that cuts through this. It looks, statistically, at the relationships between rainfall characteristics (intensity, duration, and the interval between rainstorms) and ties this in to properties of the receiving waters. We feel that can develop an approach that enables one to operate from a rainfall record into violation frequencies in the receiving water. Then, you may wish to make a more precise study, later.

Comment (Lumb): My experience is that it is next to impossible to go from precipitation probabilities to runoff probabilities. I am sure that it is also equally impossible to go from precipitation probabilities to water quality probabilities. You suggested picking a number of different storms for analysis. It appears that you are talking about continuous simulation. Would you care to comment on whether this is advisable, or needed?

Driscoll: We will tend to study smaller urban areas. This may modify the rainfall-runoff probability.

Comment (Lumb): I think you would have more problems with small areas. You would have combined probabilities of the rainfall, the antecedent conditions and flow of the receiving water. As yet, no one has demonstrated the ability to combine these probabilities.

Driscoll: The receiving water flow may have to be handled separately and be separately interfaced with the output.

Comment (Condon): Earlier, I gave a short answer to the man who asked about the first flush, and my answer was too short. When we set sampling programs, we always had very short time increments between the sampling periods in the beginning. We did have changes in concentration. The reason for the short time increments was not only to identify the first flush, but also because most of the pollutant loads, on an annual basis, come from high-frequency, low intensity rainstorms. We didn't want to miss these, so we set very short increments. Our idea is that if you get the first one and one-half hours, you have the best, and the most, you can get. You can go by flow measurements for anything later than that because you will have an average concentration. Although the flow does overweigh the total mass emission, you can use the flow with the earlier concentration.

Driscoll: I didn't mean to imply that we would miss the half-hour sampling interval. You would start sampling as soon as the storm starts. But, you can composite the samples over a one-hour period.

QUESTIONS AND ANSWERS

(Following Eugene Driscoll's paper "Runoff and Quality")

Comment (Francis Condon, EPA, Washington, D.C.): In my talk this morning in respect to the first flush, I was talking about the frequency of sampling in trying to get quantitative data. I would like to give you some insight into some of the information that I am trying to put together. The graph you showed and what you said was perfectly true, but it was a 14-hour storm. Perhaps, one-hour composite samples would be worthwhile in reducing the amount of analytical work required. I did a study on the Ohio River Valley. Over 80% of the pollutant load, on an annual basis, from urban areas came from storms that produced less than 0.1 inch of precipation with overflow periods of less than two hours duration. I am saying that we should really have a higher number of samples and that samples should be taken more frequently in the early part of any storm. Because it is a random thing, you don't know how long the discharge is going to last. So, make sure that you catch the frequent, low-intensity storms. Secondly, although we do not yet have enough data, I think you can get statistical relationships between different pollutants for a particular urban area if you take enough discreet samples. Then, later on, you may only have to sample for one pollutant--and then predict, with reliability, what the others pollutants are. Finally, I thought that the plot you showed on floatables, depicting daily or hourly variation, was excellent. I think that you must exercise care. For example, you pointed out that, because their cumulative effect is evident only in years or decades, you only have to be concerned about the annual load of nutrients. You must still collect some hourly data in order to multiply it through with the runoff events to compute the annual load. You gave the impression that you only have to take one or two samples per year for nutrients. I don't believe you meant that. I hope you didn't!

Although those events produce long-term, long-range degradation, you must still have the base of hourly information on rainfall-runoff relationships to be able to predict an annual load.

Driscoll: I certainly agree with what you said about nutrients and the time scales. Those time and space scales are guides. It is a perspective. I certainly did not mean to imply that you should measure nutrients only once per year. You must measure it often; but in analyzing the data, you may only have to look at an annual or monthly average load. My point was that one doesn't have to know the amount of nitrogen or phosphorus that is entering a stream, minute-by-minute or hour-by-hour. I want to know what the cumulative effect is, storm-by-storm or month-by-month. Your second point, concerned the possibilities for developing statistical relationships between different pollutants as they are tied in to inflow to streams. This would be very good. How well this can be done is a function of how much data is available. Your third point concerned sampling frequency. I couldn't agree with you more--that we don't want to miss those one-hour storms, whether they are low intensity or high intensity, short-duration storms, like thunderstorms. For the level of definition of a load, in terms of most receiving waters, it may not be important to know how the load enters a stream at 10-minute intervals. It may be entirely adequate to know what the average of that load is over an hour's period. A big chunk of the waste load is going to be discharged within the first hour after it stops raining, simply because the majority of rainstorms don't last very long. The sampling technique, and how you put together your composite sample, is important. In many cases, you won't need the internal definition of the variability within an hour--as long as you have the hour period represented appropriately. Is that clear?

Question (Richard Field, EPA): For treatment and control design, wouldn't you want to use shorter sampling intervals than for determining receiving stream impacts?

Driscoll: It is likely that considerations of treatment devices will require shorter levels of definition than will the receiving waters.

Comment (Field): If we think only in terms of gross receiving water impacts, we might lose certain data that we want later on for more detailed design.

Driscoll: I don't have a precise answer now as to what the breakoff on the treatment device is. I doubt very much that it will be 5-minute or 10-minute intervals.

Question (Field): There are certain catchments in highly-urbanized areas and combined-sewer areas having 50 acres or less area. The drainage may be into potentially small streams where, during a summer storm, you can get an entire effect in, say, 15 or 20 minutes. So, shouldn't the sampling frequency be set up with those considerations in mind; i. e., what does the receiving water look like, and what is the size of the drainage area and the time of concentration? You may want more definition that ½-hour composite samples can provide.

Driscoll: That is absolutely right. The whole point to all this is that these comments almost have to be generalizations. To really determine what is appropriate in any particular area requires that you address the local situation and apply these constraints and this perspective within that framework.

Comment (Field): I would like to discuss the first-flush effect that you discussed earlier. You showed a graph for mass emissions where it was indicated that there was not a first-flush effect. You indicated that the first-flush is more a function of a primary variable "Q". You indicated that this is more indicative of separate-sewered areas, which it is. But, it is easier to pick up the first-flush effect in the combined-sewer areas where there is a chance of dry-weather buildup in a low-gradient sewer serving impervious land areas where there is more dust and dirt accumulation during antecedent dry periods. A thing that you mentioned that disturbs me a little is "sample at outfalls". I would like to indicate the difference between an outfall and a point located a little upstream of the diversion weir or orifice. The outfall will get the overflow, or excess. In many areas there is a stratification phenomen. This is more true in combined sewer areas. At the lower reaches of the sewer flow, there is higher concentration of pollutants. Future plans may do away with such a dam, and by sampling only the outfall a significant solids load may be missed. This is just a word of caution as to potential differences which can readily exist in loadings.

Driscoll: Your point is well taken. I intended to refer to the outlet of the particular drainage area.

APPLICATIONS OF STORMWATER MANAGEMENT MODELS

by

John A. Lager, Vice President
Metcalf & Eddy, Inc., Palo Alto, California

INTRODUCTION

Stormwater management models offer one of the most useful tools for system evaluations; however, the uninitiated may find them an unbearable load of data requirements, programming bugs, and misunderstanding. In this lecture we will describe a model selection procedure designed to avoid the more common problem areas, briefly present the array of available models, and compare by example the alternatives of simplified and dynamic modeling applications.

Planning vs. Design Objectives

As used in this presentation the planner is assumed to be viewing broad and significantly different development senarios, perhaps basin-wide in scope; whereas the designer is more closely allied to casting his solution into concrete. Obviously, the modeling precision requirements of the latter is much more demanding; however, the range of possibilities to be evaluated is also more restricted.

Modeling Limitations

Models follow operating rules without exception or interpretation and can process mountains of data with relative ease. The developer sets the rules (and in most cases options), and the user furnishes the data and is left with the results.

That is the package, plain and simple.

In deciding whether or not to model, the potential user should assess this process closely. What are the data he is prepared to give or invest in? What are the operating rules that he is willing to live by? Where are the mountains he wishes to overcome? What will he do with the results? The faults are as obvious as the potential benefits--weak or incorrect rule(s), erroneous or inadequate data, poorly selected or defined mountains, unusable or indeterminant results (i.e., what is the message?). A poor data base cannot be overcome by a very sophisticated model.

SELECTION PROCEDURE

Stormwater management models vary significantly in degree of complexity, solution technique, and costs. It is important, therefore, that the user know beforehand the expected model performance and utility of the results.

Definition of Study Objectives

Study objectives should be specific. Why? To facilitate communication, focus of effort, and commitment. For example, if the study objective is simply to

> Comply with the requirements of PL 92-500

it is unlikely that any two people in the chain of authority will have the same idea in mind except by default. On the other hand, if the objective were amplified to

> assess the relative impact of the non-point discharges of urban runoff from within the city limits of Boomtown to other controllable sources on Segment V of the High Flow River with respect to organic loadings, given that loadings from Segment VI to V will not change from today's level. It is intended that loadings be assessed for two seasonal occurrences...

the chance of common understanding would be greatly improved, and the specifics of model requirements and applicability would be well underway to identification.

The following, then, are the types of information that require definition in the model selection phase.

Improve What, How Much, and Where. Suppose a city is investigating the use of polymers to reduce pipeline friction and thereby increase interception of flows for treatment at the dry-weather plant, as opposed to constructing a satellite overflow treatment facility. Models operating off the same input data (hydrology, catchment characteristics, pipe networks, etc.) would offer an excellent tool for weighing the two alternatives. Simplified models could be used to estimate the expected number of occurrences annually before and after improvements, and detailed dynamic models could identify design criteria for specific critical events.

Other representative questions that should be considered in setting the study objectives include the following:

1. Is flooding the major consideration? If so, then the use of a dynamic backwater model is essential. Why? Because flooding is the result of a system's inability to react to a specific storm event in the the required time interval (i.e., bottlenecks).
2. Is loading on the receiving stream the control? If so, is the nature of the impact short term (indicating the need for dynamic modeling) or long term (simple models--i.e., Streeter-Phelps--may suffice).
3. Is there a repetitive, defined occurrence that is to be abated? For example, an overflow occurrence to be reduced to keep bathing beaches open for the maximum number of days in season? Note that in bacterial contamination the occurrence or nonoccurrence of an overflow is more important than its duration.

4. What are the keys to the system's performance today? A major study objective may be to determine what makes the system respond the way it does. That is, what and where are the controls and how do they react?

5. Are there available facilities that are not being put to maximum use or to effective use? These may dictate some trial criteria for abatement schemes.

6. Are the funds available on the basis of the ability to sell the program? This again is a question of communications and timing.

7. What is the balance between the known (given) data and the assumptions? How will this change over time? An exquisite model running on a series of assumptions may yield no better results than a simple model run on the same base data.

Required Sensitivity of Results. If the ranges of given variables are known, then the model selected must be sufficiently sensitive to display output differences within such ranges. Also, the modeling requirements might be quite different if the model's purpose is to locate points on the system where monitoring information would be most beneficial, as opposed to additionally projecting expected flow and concentration ranges at such locations.

Other Constraints. Other constraints include the user or reviewer, the boundaries of the investigation (including boundary transfers), timing and budget, and operating personnel and hardware. In order to be implemented, the results or operations of the model must be made known to, and approved by, some person or persons. What are his requirements and needs? What are the milestone dates of the project, and what information must be deliverable by these dates? Will the budget resources support the study objectives? Are direct interfaces with other current modeling/data management operations essential or desirable? Finally, the output must be recognizable and usable in terms that the client can easily relate to and work with, for after all, he has to sell it.

Above all, modeling is an art and should be carried out only under the direct supervision of a professional.

Assessment of Existing Data

Models require input data upon which to operate, whether the data are real or fabricated. Also, the quantity and quality of the data base is likely to change over the course of the work. To select model programs effectively requires that the available data base strengths, weaknesses, and dynamics be identified beforehand.

Static or Fixed Data. This data is available in the early stages of a project and includes such data as the plans and specifications of the system, historical rainfall and stream flow records, census tract enumerations, planning and zoning documents, aerial photographs, treatment plant records, files on trouble calls and system maintenance, prior studies and reports, monitoring records, and state-of-the-art literature.

Generally, the most prized data represent cause-effect relationships. Examples might include changes in plant inflow characteristics between dry- and wet-weather periods; measured rainfall-runoff-quality relationships; intensive stream surveys correlated with development, treatment performance, and ideally, storm occurrences; and documentation as to the time, location, and duration of overflows.

Dynamic or Progressively Increasing Data. These are the data that will become available during and subsequent to the study. To what extent can this effort be modified or redirected to suit the needs of a specific model? At what milestone points can "midpoint" corrections be made both in the modeling and data gathering programs? A major advantage of dynamic modeling is that it may identify the key nodes that control or directly reflect system efficiency. Concentrating dynamic data gathering at these nodes may be far more cost effective than, say, a shotgun or intuitive approach.

As a note of caution in setting a value on the dynamic data: one storm does not represent a season, and one season does not represent a historical record; however, the ability or inability of a quantity of flow to get from point A to point B may be both significant and repetitive.

Assessment of Data Needs and Assumptions

Each model has a specific set of data requirements. Comparing these with the previously identified given data base will identify the proportions of the assumed data base or the dependency of the results on default values. It should be noted that the data requirements for a specific dynamic model may be so exhaustive as to require several months to collect, check, and apply. As an alternative, or during the interim period, simplified models may be run to identify gross sensitivities and possible critical data gathering points or information.

Statics. Typical static assumptions may include friction factors, infiltration ratios, retention storage, daily flow cycles, pre-storm conditions, diffusion coefficients, decay and replenishment rates, boundary exchanges, accounting for non-modeling discharges, etc.

Dynamics. Dynamic assumptions may include the computational time steps, the "design" event (may be approached through trial and error executions), treatment-cost efficiencies, imperviousness and directly contributing impervious areas, as well as any of static assumptions where special effort is to be taken. The point is to make a realistic, pre-application appraisal of what types of sensitivity analyses are likely to be performed and whether or not they are likely to be converging.

Array of Model Characteristics

Mathematical model usage in stormwater management is basically a creation of the last decade, and application experience is even more limited (SWMM was first marketed in 1971). Significantly, the more sophisticated models are in a continuous state of refinement and modification as new uses are attempted or requirements are identified. Documentation, availability, consultation advice, and record of use are equally variable and changing.

Where to Find Information. A comprehensive evaluation of stormwater management models is contained in the study, "Evaluation of Mathematical Models for Engineering Assessment, Control, Planning, and Design of Storm and Combined Sewerage Systems," prepared by Battelle Memorial Institute for EPA [1]. The complete report covers model reviews, model selection criteria, detailed descriptions of selected models, test data and results, cost comparisons, and a source listing.

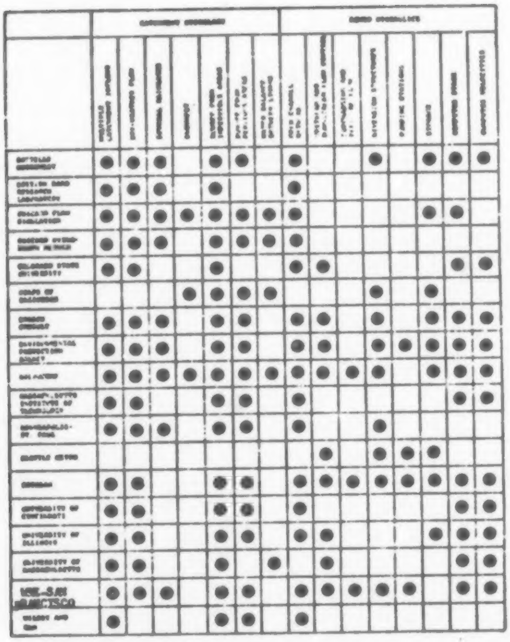
Selected summaries from this and other recent comparative evaluations [2, 3] are shown in Tables 1, 2, and 3 along with the identified references. The models are separable by function (planning, design, operation) and by degree of precision (simple, intermediate, and complex). The purpose in presenting the three similar listings is to illustrate the perspectives of these experienced users.

What (Engineering-Hydraulic) Processes are Being Simulated? The user should screen candidate model documentation to identify what processes or devices are being simulated and linked and with what degree of sophistication. Does the model focus suit the need focus? For example, the Hydrocomp Model is a multigeneration descendent of the Stanford Watershed Model. The original model dealt largely with unimproved watersheds to determine yields, streamflows, and flood characteristics. Thus, its strengths may be presumed to lie in representation of the natural hydrologic cycle. On the other hand, the WRE-SWMM transport model modifications were developed specifically for complex urban pipe networks where flow reversals, backwaters, and special diversions are not uncommon. The differentiation is obvious.

Getting from rainfall to runoff quantities may be as simple a process as applying a direct percentage (perhaps not a bad assumption when the percent imperviousness is high), or it may be a sophisticated accounting of depression storage, infiltration rates, and surface and channel flows. Or it may be an even more sophisticated accounting of soil types and moisture content, vegetation, ground slopes, air temperature, wind direction, etc.

A good model should be able to cope not only with "normal" conditions but the abnormal, such as bypassing, surcharging,

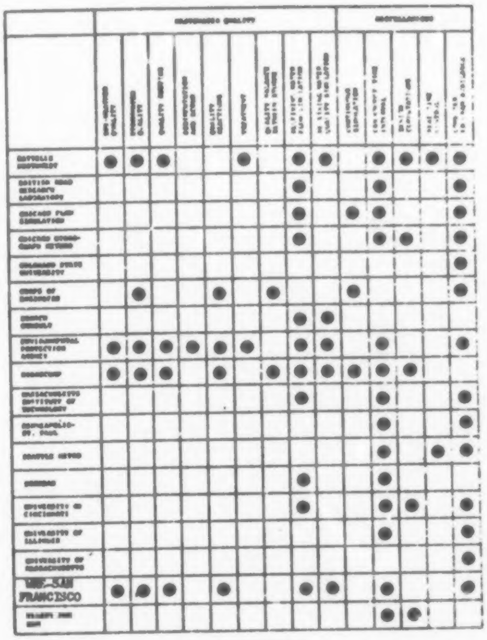
Table 1. MODEL CHARACTERISTICS BY BRANDSTETTER [1]



	[illegible]							[illegible]							
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	●	●	●		●	●		●			●		●	●	●
[illegible]	●	●	●		●			●							
[illegible]	●	●	●	●	●	●	●	●					●	●	
[illegible]	●	●	●		●	●	●	●							
[illegible]	●	●			●			●	●					●	●
[illegible]				●	●	●	●				●		●		
[illegible]	●	●	●		●	●		●	●		●		●	●	●
[illegible]	●	●	●		●	●		●	●		●	●	●	●	●
[illegible]	●	●	●	●	●	●	●	●	●	●	●		●	●	●
[illegible]	●	●			●	●		●						●	●
[illegible]	●	●	●		●	●		●			●				
[illegible]									●		●	●	●		
[illegible]	●	●			●	●		●	●	●	●	●	●	●	●
[illegible]	●	●			●	●		●						●	●
[illegible]	●	●			●	●		●	●				●	●	●
[illegible]	●	●			●		●		●					●	●
WRE-SAN FRANCISCO	●	●	●		●	●		●	●	●	●	●		●	●
[illegible]	●				●	●		●							

TABLE I

MODEL CHARACTERISTICS



	[illegible]									[illegible]				
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	●	●	●			●		●	●		●	●	●	●
[illegible]								●			●			●
[illegible]								●		●	●			●
[illegible]								●			●	●		●
[illegible]														●
[illegible]		●			●		●			●				●
[illegible]								●	●					
[illegible]	●	●	●	●	●	●		●	●		●			●
[illegible]	●	●	●		●		●	●	●	●	●	●		
[illegible]								●			●			●
[illegible]											●			●
[illegible]											●		●	●
[illegible]								●			●			
[illegible]								●			●	●		●
[illegible]											●			●
[illegible]														●
WRE-SAN FRANCISCO	●	●	●		●			●	●		●			●
[illegible]											●	●		

TABLE I (CONT'D)

Table 2. MODEL CHARACTERISTICS BY HUBER [2]

IDENTIFICATION OF CURRENT URBAN RUNOFF MODELS AND REPRESENTATIVE REFERENCES

1. Rational Method	ASCE, WPCF, *Design and Construction of Sanitary and Storm Sewers*, ASCE, 1969
2. Chicago	A.L. Tholin, and C.J. Keifer, "The Hydrology of Urban Runoff," *J. San. Eng. Div., ASCE*, Vol. 85, No. SA2, Mar. 1959
3. Unit Hydrograph	P.S. Eagleson, "Unit Hydrograph Characteristics for Sewered Areas," *J. Hyd. Div. ASCE*, Vol. 88, No. HY2, Mar. 1962
4. Unit Pulse	H.S. Grigg., et al., "Metropolitan Water Intelligence Systems," Completion Report, Phase II, Water Resource Systems Program, Dept. of Civil Engineering, Colorado State University, June 1973
5. STORM	"Urban Runoff, Storage, Treatment and Overflow Model – STORM" Hydrologic Engineering Center, U.S. Army Corps of Engrs., Sept. 1973
6. RRL	J.B. Stall and M.L. Terstriep, "Storm Sewer Design – An Evaluation of the RRL Method," EPA-R2-72-068, Oct. 1972
7. MIT	Harley, B.M., Perkins, F.E., and P.S. Eagleson, "A Modular Distributed Model of Catchment Dynamics," MIT Parsons Laboratory Report No. 133, Dec. 1970
8. Battelle	A. Brandstetter, R.L. Engel, and D.B. Cearlock, "A Mathematical Model for Optimum Design and Control of Metropolitan Wastewater Management Systems," *Water Resources Bulletin*, Vol. 9, No. 6, Dec. 1973
9. EPA-SWMM	*Metcalf and Eddy*, University of Florida, Water Resources Engineers, "Storm Water Management Model," EPA Reports 11024 DOC 07 to 10/71, July 1971
10. WRE-SWMM	R. P. Shubinski and L.A. Roesner, "Linked Process Routing Models," Spring Meeting, American Geophysical Union, Washington, D.C., Apr. 1973
11. Cincinnati (UCUR)	C.N. Papadakis and H.C. Preul, "University of Cincinnati Urban Runoff Model," *J. Hyd. Div., ASCE*, Vol. 98, No. HY10, Oct. 1972
12 DORSCH (HVM)	H. Klym, W. Koniger and G. Vogel, "Urban Hydrological Processes, Computer Simulation," Dorsch Consult, Munich, Toronto, 1972
13. SOGREAH	"Mathematical Flow Simulation Model for Urban Sewerage Systems," Caredas Program, Partial Draft Report, SOGREAH, Grenoble, Apr. 1973, (Translation by Battelle Northwest, Dec. 1973)
14. Hydrocomp	"Hydrocomp Simulation Programming Operations Manual," Second Edition, Hydrocomp International, Inc., Palo Alto, July 1969
15. Illinois (ISS)	B.C. Yen, "Methodologies for Flow Predictions in Urban Storm Drainage Systems," University of Illinois, Water Resources Center, Report UILU-WRC-0072, Sept. 1973

COMPARISON OF URBAN RUNOFF MODELS, MARCH 1974

Model	Surface Routing	Sewer Routing	Quality Routing	Degree of Sophistication of Surface Flow Routing	Degree of Sophistication of Sewer Flow Routing	Accurate Modeling of Surcharging	Flexibility of Modeling of Sewer Components	Explicit Modeling of In-System Storage	Treatment Modeling	Receiving Model Available	Degree of Calibration/ Verification Required	Simulation Period	Availability	Documentation	Data Requirements
Rational Method	Peak Flows Only	Peak Flows Only	No	Low	Low	No	Low	No	NA	No	Usually not verified	Individual storms	Non-proprietary	Good	Low
Chicago	Yes	No	No	Moderate	NA	NA	NA	NA	NA	No	Moderate	Individual storms	Non-proprietary	Fair	Moderate
Unit Hydrograph	Yes	In combination with surface	No	Low	Low	No	Low	No	NA	No	High	Individual storms	Non-proprietary	Fair	Moderate
Unit Pulse	Yes	In combination with surface	No	Low-Moderate	Low-Moderate	No	Low	No	NA	No	High	Individual storms	Non-proprietary	Fair	Moderate
STORM	Yes	In combination with surface	Yes	Low	Low	No	Low	No	Yes	No	Low	Long term	Non-proprietary	Good	Moderate
RRL	Yes	Yes	No	Moderate	Low-Moderate	No	Low	No	NA	No	Moderate	Individual storms	Non-proprietary	Good	Moderate
MIT	Yes	No	No	High	NA	NA	NA	NA	NA	No	Moderate	Individual storms	Proprietary	Fair	Moderate
Battelle	Yes	Yes	Yes	Low	Moderate	No	Moderate	Yes	No	No	Moderate	Individual storms	Non-proprietary	Poor	Moderate
EPA-SWMM	Yes	Yes	Yes	High	Moderate	No	High	Yes	Yes	Yes	Moderate	Individual storms	Non-proprietary	Good	Extensive
WRE-SWMM	Yes	Yes	Yes	High	High	Yes	High	No	Yes	Yes	Moderate	Individual storms	Proprietary	Poor	Extensive
Cincinnati (UCUR)	Yes	Yes	Yes	High	Low	No	Low	No	No	No	Moderate	Individual	Non-proprietary	Fair	Extensive
Dorsch (HVM)	Yes	Yes	No	High	High	Yes	High	?	NA	Yes	Moderate	Individual storms	Proprietary	Poor	Extensive
SOGREAH	Yes	Yes	?	High	High	Yes	High	?	?	Yes	Moderate	Individual storms or separate Individual storms	Proprietary	Poor	Extensive
Hydrocomp	Yes	Yes	Yes	Moderate	Moderate	No	Low	No	No	Yes	High	Individual storms or long term	Proprietary	Fair	Extensive
Illinois (ISS)	Yes	Yes	No	Moderate	High	No	Low	No	NA	No	Moderate	Individual storms	Non-proprietary	Good	Extensive

Table 3. MODEL CHARACTERISTICS BY ROESNER [3]

Reproduced from
best available copy.

UTILITY OF URBAN RUNOFF MODELS FOR VARIOUS STAGES OF STORMWATER MANAGEMENT PLANNING

	STORM	MITCAT	HYDROCOMP	EPA SWMM	SF-WRE
Large-Scale Planning (Alternative Screening)	Excellent	Good	Good	Poor	Poor
Intermediate Scale Planning	Poor	Excellent	Excellent	Excellent*	Excellent*
Detailed Planning/Analysis (No Significant Backwater)	Poor	Excellent	Fair	Excellent	Excellent
Detailed Planning/Analysis (Complex Drainage Networks)	Poor	Poor	Poor	Fair	Excellent
Runoff Quality Simulation	Yes	No	Yes	Yes	Yes
Flow Computation	Rational Formula	Kinematic Wave	Kinematic Wave	Kinematic Wave + Planning Equ. with Dynamic Continuity	Kinematic Wave + Complete Dynamic Flow Equations

*The Runoff Model is best suited for these applications.

REFERENCES AND MODEL ACQUISITION

STORM

Description

Roesner, L.A., et al., Water Resources Engineers, The Hydrologic Engineering Center/Corps of Engineers, and Department of Public Works/City and County of San Francisco, "A Model for Evaluating Runoff-Quality in Metropolitan Master Planning," ASCE Urban Water Resources Research Program, Technical Memorandum No. 23, New York, N.Y., April 1974.

Acquisition - In Public Domain

1. Hydrologic Engineering Center/Corps of Engineers, Davis, California
2. Water Resources Engineers, Walnut Creek, California

MITCAT

Description

Harley, B.M., F.E. Perkins and P.S. Eagleson, "A Modular Distribution of Catchment Dynamics," Massachusetts Institute of Technology, Cambridge, Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, Report No. 133, December 1970.

Acquisition - Proprietary

Resource Analysis, Inc., Cambridge, Massachusetts

HYDROCOMP

Description

Crawford, N.H. and R.K. Linsley, "Digital Simulation in Hydrology: Stanford Watershed Model IV," Stanford University, Palo Alto, California, Department of Civil Engineering, Technical Report No. 39, July 1966.

HYDROCOMP - Continued

Acquisition - Proprietary

Hydrocomp International, Inc., Palo Alto, California

EPA SWMM

Description

Metcalf & Eddy, Inc., University of Florida and Water Resources Engineers, Inc., "Storm Water Management Model," U.S. Environmental Protection Agency Report 11024 DOC 07/71, 4 Volumes, October 1971.

Acquisition - In Public Domain

Storm and Combined Sewer Technology Branch-EPA, Washington, D.C.

SF-WRE

Description

Shubinski, R.P. and L.A. Roesner, "Linked Process Routing Models," Paper Presented at American Geophysical Union Annual Spring Meeting, Washington, D.C., April 1973.

Acquisition - In Public Domain essentially

1. Division of Sanitary Engineering, Department of Public Works, City of San Francisco
2. Water Resources Engineers, Walnut Creek, California

The following document gives, for the most part, a good and fair comparison of the capabilities of eleven urban stormwater models:

Brandstetter, Albin, "Comparative Analysis of Urban Stormwater Models," Battelle Memorial Institute, Richland, Washington.

overbank flooding, etc., without losing flow-mass contiuity or tripping out.

MODELING FOR RESULTS

The success or failure of a modeling attempt can be judged only by the buyer. Did he get the information he needed when he needed it? For the price he expected to pay for it? If an initial attempt was a failure, where did it go wrong--objectives, data base, model capabilities, assumptions? If it was successful, where does the credit lie?

Decision Output Data

The display, listing, or packaging of the output data may be as important to the decision maker as the data itself. Are the output values to be accepted because they display eight significant figures or because the cause and effect relationships are visible, reasonable, and capable of verification? If the output is voluminous, where are the checks and balances? How is it displayed? If part of the computation was made outside the game rules, how is it signaled? Corrected? If a trace back into the simulation is required, can one obtain intermediate results at a specific location in the system? At a specific point in the computations? How about restarts to avoid repetitious computations?

A point, perhaps understressed heretofore, is the value of accuracy in the results. A dynamic model may give the impression of a very true result for a clean, circular conduit where, in fact, 50 percent of the line is in a state of collapse, subsided, or filled with debris. How valuable is representing the response of a new system when you are stuck with the one you have? Further, if the transfer of quality data from Transport or Storage to Receive is to be accomplished in hourly blocks, is it necessary that it be compared at 5-minute intervals? The answer, of course, goes back to the study objectives as to what is to be improved, how much, and where.

Building Block in Continuing Program

One of the advantages of modeling is that almost as much value might be obtained from a technically failed run as from a successful one. Why? Because the effort of system analysis that goes into preparing for and executing a run forces the issue into areas that have traditionally fallen into neglect as lost items within a city budget. In selecting a model, the user should assess its impact on his broader continuing program. If the present objectives are met, what is the next step? Will models again be a requirement? Should the experience and data base be built up now in preparation?

Does It Fit

In summing up all of the above selection criteria, it is seen that there are both choices and opportunities in modeling urban stormwater runoff. Finding the model of best fit is best approached by a systematic appraisal, such as the one outlined herein, with emphasis on the pre-selection definition of study objectives.

COMPARATIVE EXAMPLES

In the author's experience, there are basically two levels of approach available: the simplified and the detailed. The advantage is that, when understood, they can and should be entirely complementary. The advantage of the simplified models is their ability to process long periods of record and broad areal coverage at low cost. The advantage of the detailed models is their ability to make a comprehensive analysis of singular events and systems with a corresponding increase in accuracy when supported by a viable data base.

In planning studies, the simplified models offer a flexible screening device to identify consequential storm events and potentially attractive alternatives. The detailed models permit the necessary follow-up and technical evaluation between competing plans.

Simplified Models

Simplified math models or their equivalent analyses are needed for three reasons:

- To introduce time and probability to stormwater analyses
- To promote total system consciousness on the part of the user or reviewer
- To establish size-effectiveness relationships

Just as time and probability analyses are important in sizing water supply impoundments and safe yields, they are--or should be--equally important in determining the effective use of stormwater facilities. Since total capture is not a necessary goal, as opposed to flood control works, there is greater latitude in facility sizing and staged implementation. The trick is determining the relative merits of alternatives, a task for which modeling is ideally suited.

Subsystems. There are typically three subsystems in simplified models: (1) rainfall characterization, (2) storage-treatment balance, and (3) discharge-receiving water response.

> Rainfall Characterization - Rainfall characterization is basically a sorting and ranking of historical rainfall data from local gages. It requires a simple but precise storm event definition to permit disassociation of chronological sequence for statistical analysis. Official Weather Bureau recordings of hourly data are a practical data source. It is useful in determining the recurrence frequency of particular storm events or event series.
>
> Storage-Treatment Balance - Storage-treatment balance models take historic rainfall data in chronological sequence as input and log quantities, times, and durations of overflows for selected storage-treatment combinations.
>
> Discharge-Receiving Water Response - Discharge-receiving water response models apply significant quality characteristics to the discharges and predict their behavior in the receiving stream. The latter model can be very complex, particularly in an estuarine environment.

The storage-treatment balance concept is shown in Figure 1. In the simulation, historical rainfall is read in chronological order, converted by a factor (coefficient of runoff) into runoff, and stored in a specified volume which is emptying at a specified rate. When the runoff exceeds the combined storage-treatment rate, an overflow occurs. Initial runs are executed on a daily basis for the full period of record and over the range of the viable alternatives.

For periods of greatest interest, those producing overflows, repeat runs may be cycled on an hourly basis to develop a hydrograph and refine the storage-treatment simulation.

The program is used by varying the storage capacity and treatment rates, and noting the changes in overflow occurrences and durations. Input variables at the present time are simply the land area, runoff coefficient, storage capacity, and treatment rate.

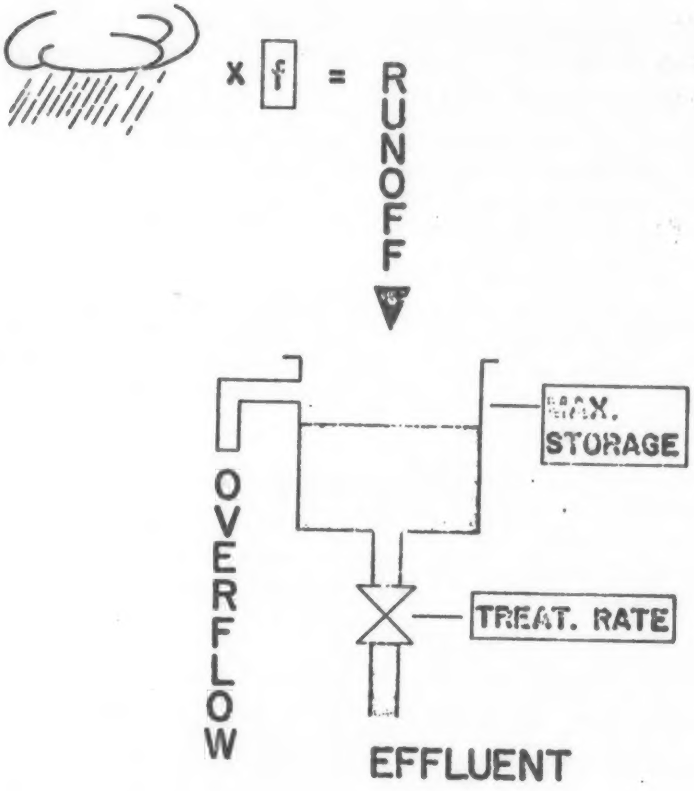


Figure 1. CONCEPT

Dynamic Models

Dynamic models are typified by the Stormwater Management Model (SWMM) developed for the EPA by Metcalf & Eddy, Water Resources Engineers, and the University of Florida in 1971. They are capable of modeling every step in the rainfall-runoff-treatment and discharge process in both quantity and quality. Single events are modeled with rainfall input from one or several gages at 5-minute intervals. Runoff begins with overland flow, infiltration and ponding, and proceeds as gutter flow and through a detailed simulated collection system to points of storage, treatment and overflow. Continuous hydrographs and pollutographs are computed and ultimately disbursed in a dynamically responding receiving water.

Subsystems. Subsystems are in the form of programming blocks as shown in Figure 2.

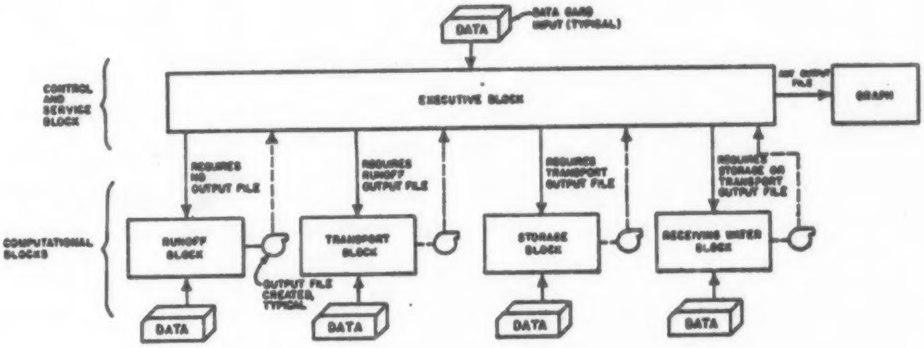

DATA
DATA CARD INPUT (TYPICAL)
CONTROL AND SERVICE BLOCK
EXECUTIVE BLOCK
ANY OUTPUT FILE
GRAPH
REQUIRES NO OUTPUT FILE
REQUIRES RUNOFF OUTPUT FILE
REQUIRES TRANSPORT OUTPUT FILE
REQUIRES STORAGE OR TRANSPORT OUTPUT FILE
COMPUTATIONAL BLOCKS
RUNOFF BLOCK
TRANSPORT BLOCK
STORAGE BLOCK
RECEIVING WATER BLOCK
OUTPUT FILE CREATED, TYPICAL
DATA
DATA
DATA
DATA

Figure 2. DYNAMIC PROGRAMMING ROUTINE

The output of each computational block is a similarly formatted tape file which can be input to any other computational block. The advantages of a dynamic model is that they are true simulations--pipes, chambers, and surface depressions fill and draw in real time sequence, pollution is washed from the ground and scoured from the pipes and channels, and finally, pollutants spread and decay in the receiving waters. The program is used by varying development patterns and land use, simulating alternative relief lines, storage basins and treatment systems and observing the effects on the receiving system.

Typical Comprehensive Application and Costs

An example of a comprehensive, eight-step program [4] capable of integrating both simplified and dynamic models is shown in Figures 3 and 4. In Step 1, the dynamic model is used over selected test areas for calibration and setting representative runoff and quality coefficients and response times. In Steps 2 and 3, the simplified model is used to select critical test hydrology and boundary conditions and to produce a modified SWMM model for total city coverage. In Step 4, the dynamic model of the receiving waters is used to identify key sampling needs which are carried out in Step 5. In Step 6, the dynamic receiving water model is reduced to a simplified model through the development of influence coefficients. This permits the running of many more alternative conditions at less cost. In Step 7, verification runs are made on both the dynamic and reduced models using the new data sets. Finally, in Step 8, the alternative plans are tested and ranked. In addition with the model developed to this high state, phased implementation can be assessed as the construction program progresses.

Costs. While there are no simple rules of thumb for estimating the costs of applying stormwater models, there are some records from past experience. For example, single computer runs using the simplified model will take less than a minute at a cost of $20 machine time. In the SWMM program, single block runs take from 1 to 5 minutes; thus putting the machine time cost for a single complete program in the neighborhood of $100 to $500. Where complex estuaries or extensive system surcharging are involved, single run costs may run several times these values. These costs do not include data gathering or calibration runs but simply machine time.

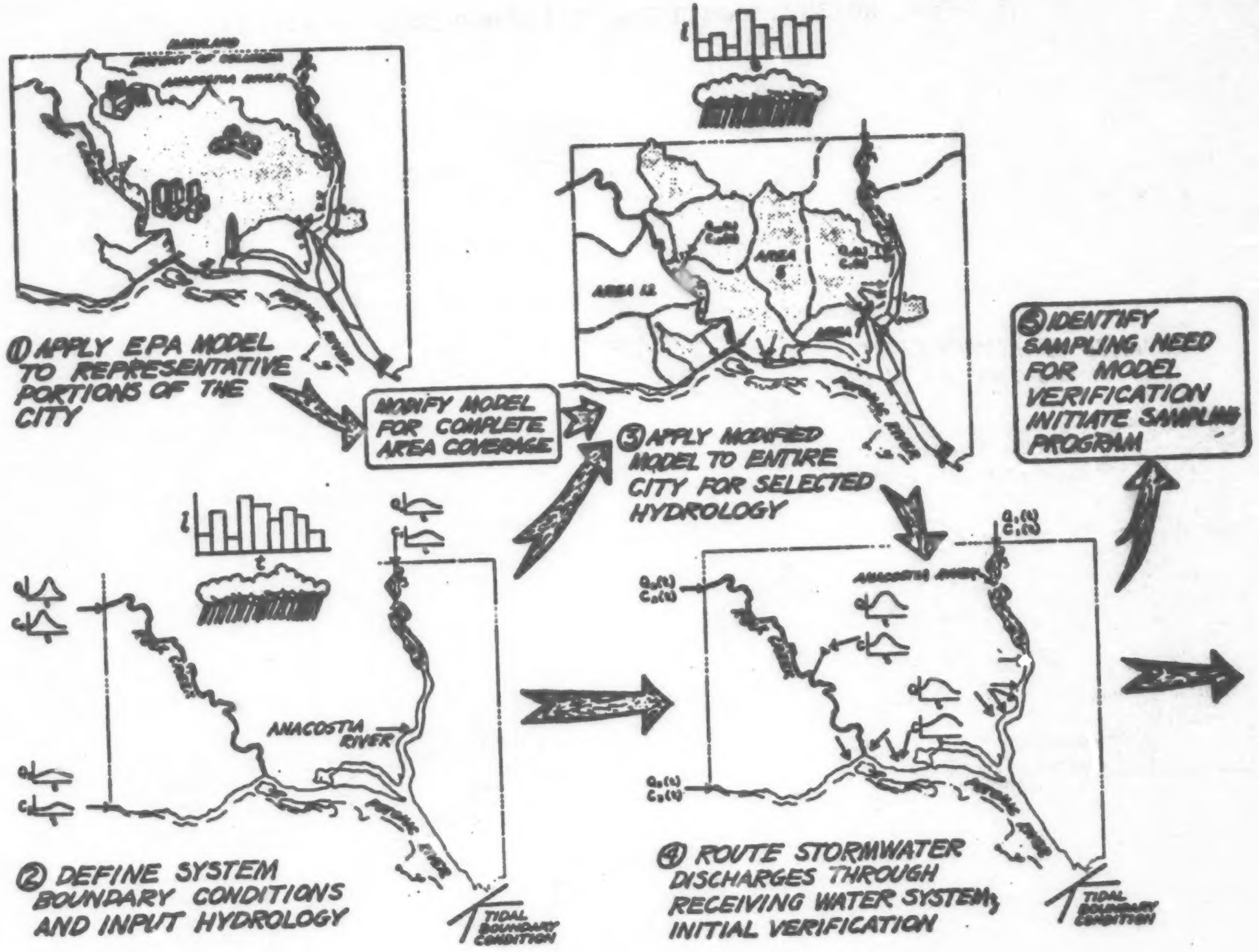

MARYLAND
DISTRICT OF COLUMBIA
ANACOSTIA RIVER
POTOMAC RIVER
① APPLY EPA MODEL TO REPRESENTATIVE PORTIONS OF THE CITY
MODIFY MODEL FOR COMPLETE AREA COVERAGE
AREA 12
AREA 6
③ APPLY MODIFIED MODEL TO ENTIRE CITY FOR SELECTED HYDROLOGY
⑤ IDENTIFY SAMPLING NEED FOR MODEL VERIFICATION INITIATE SAMPLING PROGRAM
i
t
ANACOSTIA RIVER
② DEFINE SYSTEM BOUNDARY CONDITIONS AND INPUT HYDROLOGY
TIDAL BOUNDARY CONDITION
Q₁(t)
C₁(t)
Q₂(t)
C₂(t)
Q₃(t)
C₃(t)
④ ROUTE STORMWATER DISCHARGES THROUGH RECEIVING WATER SYSTEM; INITIAL VERIFICATION
TIDAL BOUNDARY CONDITION

Figure 3. COMPREHENSIVE MODEL APPLICATION (PART 1)

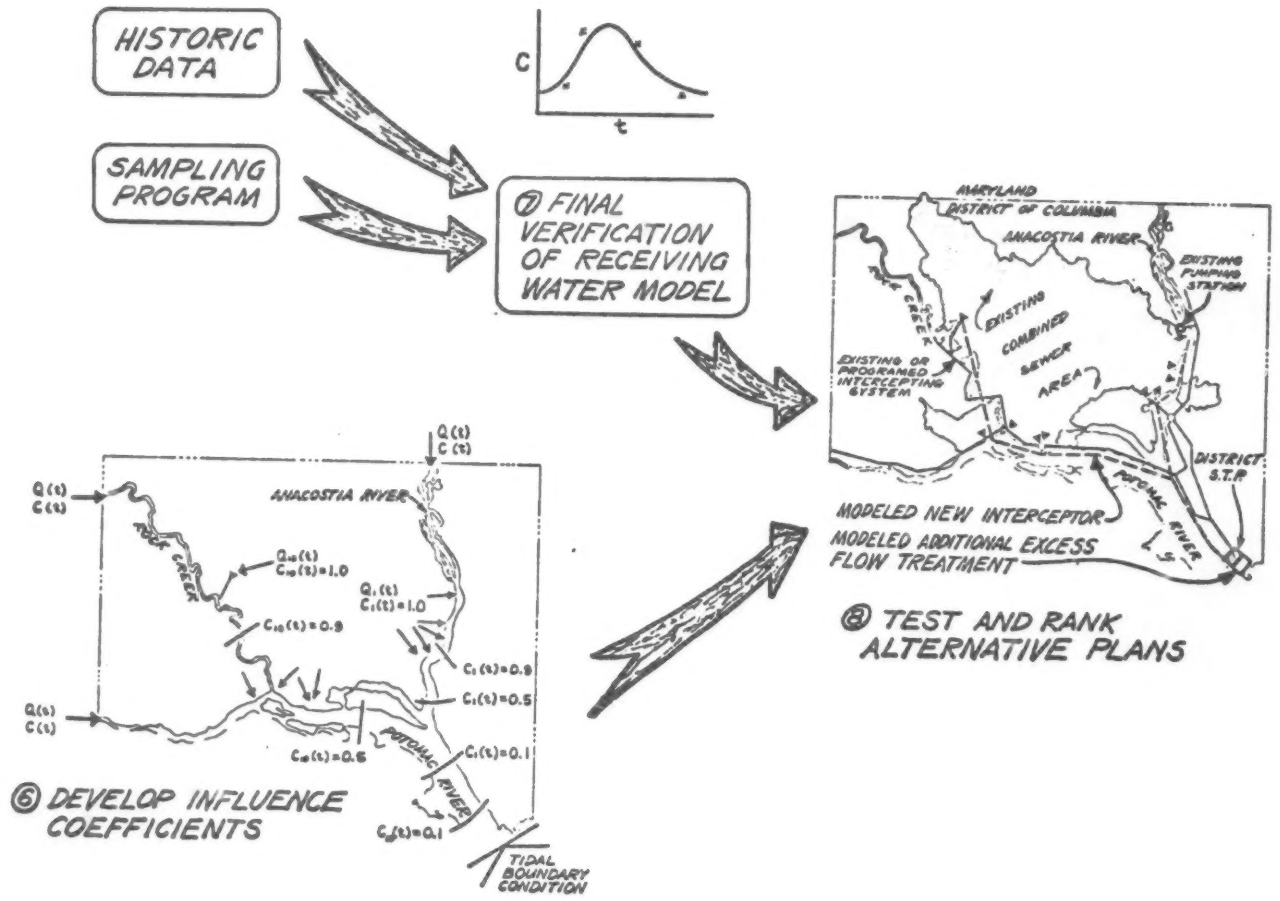

HISTORIC DATA
SAMPLING PROGRAM
C
t
⑦ FINAL VERIFICATION OF RECEIVING WATER MODEL
MARYLAND
DISTRICT OF COLUMBIA
ANACOSTIA RIVER
EXISTING PUMPING STATION
ROCK CREEK
EXISTING COMBINED SEWER AREA
EXISTING OR PROGRAMED INTERCEPTING SYSTEM
DISTRICT S.T.P.
POTOMAC RIVER
MODELED NEW INTERCEPTOR
MODELED ADDITIONAL EXCESS FLOW TREATMENT
⑧ TEST AND RANK ALTERNATIVE PLANS
Q(t)
C(t)
ANACOSTIA RIVER
ROCK CREEK
Q10(t)
C10(t)=1.0
Q1(t)
C1(t)=1.0
C10(t)=0.9
C1(t)=0.9
C1(t)=0.5
C10(t)=0.5
C1(t)=0.1
C10(t)=0.1
POTOMAC RIVER
TIDAL BOUNDARY CONDITION
⑥ DEVELOP INFLUENCE COEFFICIENTS

Figure 4. COMPREHENSIVE MODEL APPLICATION (PART 2)

A comprehensive program such as that diagrammed and including verification sampling could be expected to cost in the neighborhood of $200,000 to $500,000, including engineering time.

Also, it is interesting to note that fees for directly applying river models, ranging in complexity from DOSAG to QUAL and using only available data, ranged from about $20,000 to $80,000 under EPA's program of a few years ago.

CONCLUSIONS

Stormwater management models are widely, but sometimes not effectively, used across the nation today. It is strongly believed that a detailed selection procedure and assessment of objectives is necessary to lay out an effective modeling program. Furthermore, experienced professional assistance is the best guarantee of success, and even then, the degree of success will be heavily dependent upon the real, on-site data base.

In the author's judgement, the most cost-effective utilization of modeling in stormwater management will bring together both simplified and dynamic models in a single complementary program.

ACKNOWLEDGEMENT

Much of the material for this presentation was drawn from two previous papers by the author, presented at the EPA and University of Massachusetts-sponsored short course on Applications of Stormwater Management Models, July 28-August 1, 1975. These papers were titled, "Selection of Stormwater Management Models" and "Simplified Management Models

for Planning," and the readers are referred to the short course proceedings for further information.

REFERENCES

1. Battelle Memorial Institute. Evaluation of Mathematical Models for Engineering Assessment, Control, Planning, and Design of Storm and Combined Sewerage Systems. U.S. Environmental Protection Agency, Project No. CI-73-0070.

2. Huber, W.C. Modeling for Storm Water Strategies. APWA Reporter. May 1975.

3. Roesner, L.A. Personal communication to author. June 1975.

4. Metcalf & Eddy, Inc. and Water Resources Engineers, Inc. A proposal to the Government of the District of Columbia, Department of Sanitary Engineering for Overflow Abatement and Receiving Water Response. September 1971.

QUESTIONS AND ANSWERS

(Following Mr. Lager's paper "Application of Stormwater Management Models")

Question (David Reynolds): Suspended solids is going to be a significant problem in most 208 areas. Do you have any suggestions for techniques that can be used to address suspended solids?

Lager: Version 2 of the EPA Model SWIM includes erosion and sediment transport. It is available and it is documented.

Question: Did I understand you correctly--that in a well-run modeling program one should expect to spend between $200,000 and $500,000 for headline people? This is about $1.00 per capita. We hear that the funding guideline was $1.25 per capita for the entire program, not only for modeling. From what you say, it appears that more funds than $1.25 per capita are needed to cover the whole program.

Lager: The $500,000, I think, is an accurate figure for the central complex. But, I am not implying that it is proportioned to population. I would guess that as much as one-fourth of the total funds allocation should be used for modeling, another one-fourth for identifying alternatives and about 50% in the area of implementation and legislation for getting the work into a significant program.

Question: What does the cost figure include?

Lager: It includes going back into the system to pick up verification data at key locations. This would represent 10% of the budget. It is not a comprehensive evaluation of receiving water, which could take the whole budget figure that I quoted.

Question (Dan Goodwin, Illinois): Have the suspended solids feature of the SWIM Model ever been used successfully anywhere?

Lager: I believe it has been accepted by EPA. It was developed by the University of Florida.

QUESTIONS AND ANSWERS

(Following John Lager's paper "Applications of Stormwater Management Models")

Question (Donald Hey, Hydrocomp): One report that you missed in terms of model reviews was done by the U.S. Army Corps of Engineers Waterways Experiment Station, dated August 1975. It is probably the most complete compendium of models I have seen. It can be obtained from Jerry Brown. Concerning some aspects of previous discussions today, I strongly recommend that 208 agencies get together and talk about their experiences. Some agencies have already designed and implemented data collection programs. East St. Louis and Collinsville, Illinois are cases in point. The Triangle-J Planning Commission has already gone through a data collection program. They have encountered many of the problems that you have discussed. I strongly recommend that interested people get together with these agencies to learn of their experience.

Lager: Publications and summaries, such as the publication of the Waterways Experiment Station, are very valuable for persons who are screening all the possibilities.

Question (Joe M. Bryan, Houston-Galveston Area Council): I would like you to comment on the possibility of a desk-top analysis, using available data, for reproducing the output-runoff blocks of the stormwater management model and transferring them to the receiving water block, skipping the transport block and storage block.

Lager: If your problem is receiving-water oriented, don't get hung-up in the collection system hydraulics--because the water is going to get there. You never have a specific storm identically reproducing itself. What you want is that type of direct transfer to go immediately into receiving water impact. The fellow that is hung up with flooding problems on a collection system has an entirely different problem. The desk-top analysis is very valid when you look at the costs-about $ 20 per run. That's less than we will pay an engineer for an hour's work. This type analysis is one that we are documenting for EPA. This simplified method may give the results of 20 years of analysis of some pet theory that you have for approaches, such as how much treatment you should have for a specific area, whether a primary level of treatment should be provided at the plant versus no treatment of the storm flow, and progressive increases in treatment of storm flow. These simplified devices are quite cost-effective to put to use if you recognize their limitations.

QUESTION AND ANSWER PERIOD

(At the conclusion of the first day of seminar)

Question(Whitey Secor, Washington C.O.G.): Mr. Condon, you mentioned that automatic liquid samplers are the best and that grab sampling is not particularly appropriate. Will you clarify that, please?

Condon: The simple reason is that if you depend upon grab samples someone must go out and grab them! Unfortunately, because it rains any time of day or night, the method is unreliable. Much important data is missed.

Question: Mr. Condon, you mentioned that street sweeping studies are quite ineffective. Would you recommend that no street sweeping studies be done under 208 planning studies?

Condon: No. The studies are useful. For qualitative studies, street sweeping studies are useful. But, in quantitative studies, one begins to hesitate to predict what comes out at the outfall on the basis of the street surface samples.

Question: Mr. Condon, do you have any advice on collecting samples at sites where there is no electrical service available? And if one is considering flow-activated devices, you have a problem. You always have a vandalism problem. Do you have any advice on how to cope with these things?

Condon: I tried to mention the trade-offs, and all those things you mentioned enter into the trade-offs--in the equipment you select. I'm not going to push for any specific equipment. We do have one report available that tries to identify all the samples. I had mentioned that the site selection is just as important as equipment. The type equipment to be used influences site selection. I have a whole checklist in a report. It includes sample capacity depending upon the analysis you plan, the location, the kind of samplers, the power supply and the protection of the samples. If you want the report, write to me and ask for the "Sampler Report".

Question: Is it possible for a 208 Agency to produce a satisfactory 208 program report for EPA without a modeling effort? Is some modeling effort required just to fulfill the requirements, regardless of whether the 208 Agency feels it is worthwhile.

Athayde: The policy, as I understand it, is that modeling is to be minimized. In some cases, you can definitely do 208 plans without modeling. But, in those areas that require it, we would like you to have all the information that EPA can provide.

Question: I was disturbed that Mr. Condon used the word "must" in specifying automatic sampling. I think that you have to be concerned with cost and what you determine you can spend.

Condon: I will stand by the word "must", and will not retreat an inch. It is experience that makes me say this! If you are trying to find out what your loads are, under different conditions, and the impacts, the automatic samplers are cheaper than manpower over a period of time. Again, this is a trade-off and must be evaluated. But, if you were doing a sampling program for any project of mine, the word "must" would stand.

Question (Ken Pugh, Cleveland Regional Sewer District): Can you give me a number for combined sewer overflow discharges instead of stormwater discharges?

Athayde: There are guidelines out for combined sewers now. My understanding of the guidelines, for combined sewers, is that there is a monitoring and data collection requirement now. I am not sure that there is any number on combined sewer overflows other than receiving water quality standards for any particular area.

Comment: We have a NPDES permit for more than 500 combined-sewer overflows. We'll never meet it!

Condon: There is no national number. The EPA Regions were allowed to enforce the degree of the requirements with respect to monitoring. Some Regions are not paying any attention to it, and others are. But, there is a different approach between combined sewers and storm sewers. It is important. In the combined sewer permits, it was argued that we should not measure any receiving water impact. The logic behind this is that combined sewers are discharging raw, sanitary wastes and the whole intent of Congress was that there should be no raw sewage discharges. What we did need to know was the incidence--the frequency and how much was coming out of the system. Then there was the hopeful idea that cities having combined sewers would diagnose their collection transport systems. From that knowledge, they can, later, take remedial action based on the facts. But, there is no national number assigned to combined sewers.

II. Approaches to the Urban Stormwater Problem

Land Management Techniques for Stormwater Control in Developed Urban Areas

Kathleen Adgate
Water Planning Division
U.S. EPA

Introduction

The theme of this urban stormwater management seminar is the need to look at alternative approaches to complete treatment of stormwater, approaches of a more cost-effective and preventative nature. This paper addresses those alternative approaches specifically applicable to developed urban areas. For the purposes of this paper, the term "stormwater management" is delimited to include control of pollution in both separate and combined sewer systems.

Alternatives available for reduction of stormwater pollution have been categorized as (1) abatement, (2) control or (3) treatment.[7] Abatement measures are those practices directed toward pre-storm reduction of pollutants, such as fertilizer control, street cleaning or periodic sewer flushing. Control measures are those which impact stormwater path, flow rates or loadings, such as detention/retention basins or roof top or parking lot storage. Treatment of stormwater generally involves the physical, chemical and biological techniques applicable to treatment of wastewater flows. While these three categories--abatement, control and treatment--offer a wide range of alternative techniques for management of stormwater pollution,[1,3,15,16] their real world application is limited in many developed areas by conflicts with existing land use and activity. Table I presents a listing of stormwater management alternatives, and suggests the desirability of exploring the cost-effectiveness of land management techniques for urban stormwater control. This paper will discuss land management techniques for developed areas, often termed "housekeeping techniques," as applicable to control of urban stormwater pollution.

Discussion of Housekeeping Alternatives

Housekeeping techniques are land management practices directed toward improving urban cleanliness. While these techniques have traditionally been performed by public works departments for aesthetic purposes, there is a general correlation between urban cleanliness and improvement of water quality in urban runoff.[8,14] And because these techniques have held a traditional place in the urban environment, they have a greater opportunity for public acceptance, an essential factor in the implementation of any management plan.

To begin, let us first review the housekeeping techniques in the order that they are presented in Table I. This discussion is drawn primarily from the literature, and, because stormwater management in the quality sense is a relatively new area of concern, the available literature on these techniques is limited.

Housekeeping techniques include both abatement and control measures that impact, respectively, on quality and quantity aspects of stormwater

TABLE I

Limitations on Stormwater Management Control Alternatives in Developed Areas

Alternative Controls	High Costs	Land Conflict
• Treatment	X	X
• Land Use Planning		X
• Detention/Retention		X
• Housekeeping Techniques		
street cleaning		
solid waste management		
catch basin cleaning		
sewer flushing		
deicing material control		
roof leader disconnection		

runoff. Quality controls include street cleaning, sewer flushing, catch basin cleaning, deicing material controls, and solid waste management. The quantity control discussed in this paper is disconnection of roof leaders.

1. Street Sweeping

Materials washed off of street surfaces have been found to contribute significantly to pollution of receiving waters. One study on street surface contaminants calculated that street surface runoff pollutant loads can exceed loads from sanitary sewage.[14] The quantity of contaminant material was found to depend upon the length of time since prior cleaning, whether intentional or from rainfall. Periodic street sweeping is one housekeeping technique which can impact positively on this contaminant load.

Street sweeping may be performed by manual or mechanical methods. While machine sweeping accounts for the majority of street sweeping in this country, manual sweeping is used by many communities to supplement mechanical operations. Its purpose is to control visible debris such as paper and cans, and its primary impact is on those areas where parked cars prevent the use of motorized equipment.

Motorized street sweepers loosen dirt and debris from street surfaces and deposit them in a storage hopper. Three types of motorized equipment are currently in operation. The pickup broom type is the most common. It utilizes a rotating gutter broom to move materials into the area of a main pickup broom. A wide variety of sweepers are available within this category, including both three- and four-wheel vehicles. The regenative air type sweeper air blasts material from the street surface into the hopper. A third type of equipment, which is presently in limited use within the U.S., is the vacuum sweeper. The vacuum sweeper loosens material from street surfaces, picks it up through a vacuum nozzle. saturates it with

water and deposits it in the vacuum chamber. With a hose attachment, the vacuum sweeper can also function as a catch basin cleaner, and can provide for cleaning of porous pavements.
Table 2 presents a listing of commonly used street sweepers.

Operating speed of most street sweepers ranges from 4 to 8 mph.[14] While acceptable for street sweeping in residential and commercial areas, this speed is not sufficient for cleaning of arterials or freeways. Therefore, several manufacturers offer a four-wheel sweeper with auxiliary engine to drive the brooms, at a maximum speed of 15 mph. The use of auxiliary engines provides constant power and speed for brooms and elevators, allowing the operator to adjust sweeper speed to street conditions.

Street surface contaminants are not uniformly distributed across a street.[14] Table 3 displays the solids loading intensity across a typical street. It indicates that 78% of the loading is found within six inches of the curb and that 97% is within 40 inches. The basic street sweeping procedure, therefore, is to clean that area adjacent to the curb. This results in a redistribution of debris across the street surface, but does not significantly reduce the total amount of pollutants on the street surface.

Removal effectiveness of street sweeping equipment varies with particle size distribution, mass loading, street surface type and condition, and type of sweeper used.[14] The literature indicates an overall removal effectiveness of 50%, with a range from 79% for particles greater than 2000 microns to 15% removal for particles less than 43 microns (see Table 4).[14] Fifty percent of all particles on street surfaces are in the

Table 2. SOME COMMONLY USED STREET SWEEPERS

Type	Manufacturer	Model	No. Wheels	No. Engines	Main Broom Width (in.)	Side Broom Diameter (in.)	Sweeping Path	Sweeping Speed (mph)	Max. Travel Speed (mph)	Water Spray	Hopper Capacity (3 cu yd)	Comments
Pick-up brm	BLH Austin-Western	70	3	1	60	36	9 ft	1-10	25	yes	4 1/2	Model 40-B has 3-cu yd hopper
	Elgin	475 (White Wing)	3	1	68	36	8 ft	1-15	22	yes	4 1/2	Model 375 has 3 1/2 cu yd hopper
	Elgin	Pelican	3	1	68	36	8 ft	1-15	22	yes	2 1/2	Self-dumping (8ft 6in lift)
	MB	Cruiser	4	1	60	47	n.a.	3/4 & up	50	yes	4 1/3	Dumps from rear
	Mobil	TE 4	4	2	60	42	7ft 6in	1-12	55	yes	4	Model TE-3 has 3 cu yd hopper
	Wayne	984	3	1	58	45	9 ft	2-8	25	yes	4	Model 973 has 3 cu yd hopper
	Wayne	945	4	2	58	45	8 ft	1-15	55	yes	4	
	Wayne	933	3	1	58	45	8 ft	1-15	55	yes	3	Self-dumping (94 in lift)
	Murphy	4032	4	2	58	45	10 ft	1-12	55	yes	3	Self dumping (side dump)
	Murphy	4042	4	2	58	45	10 ft	1-12	55	yes	4	Self-dumping (side dump)
	Murphy	4062	4	2	58	45	10 ft	1-12	55	yes	6	Self-dumping (side dump)
Air	Tymco	300	4	2	80	Optional	6 ft 8 in	1-8	55	Optional	3	Uses "regenerative" air system
	Tymco	600	4	2	96	Optional	8 ft	1-10	55	yes	6	Uses "regenerative" air system
Vacuum	Tennant	100	3	1	42	32	6 ft	0-12	15	no	1 3/4	Uses Vac. system for dust contro
	Elgin	Whirlwind	4	2	60	28	87 in	n.a.	55	yes	5.5	Has auxiliary pickup nozzle
	Ecolotec	Vacu-Sweep	6	2	60	20	72 in	n.a.	55	yes	6.3	Has auxiliary pickup nozzle
	Coleman	Metro-vac	6	2	—	20	94 in	n.a.	55	yes	11 1/2	

NOTE: This list is not comprehensive but does include the most commonly used sweepers. Sweeping path data are using 1 side broom. The Tymco sweepers have no broom; the broom width specified is actually the width of the pickup head

Source: 14

Table 3

Street Location (Distance from Curb)	Solids Loading Intensity (% of Total)
0 - 6 in.	78
6 -12 in.	10
12 -40 in.	9
40 -96 in.	1
96 to center line	2

Source: 14

Table 4

Particle Size (μ)	% Sweeper Efficiency
> 2000	79
840 - 2000	66
246 - 840	60
104 - 246	48
43 - 104	20
< 43	15
Overall	50

Source: 14

range of 104-840 microns, where efficiencies vary from 20-60%. Particles of less than 104 microns experience removal efficiencies of less than 20%, yet contain 42% of biochemical oxygen demand, 28% of total heavy solids and 32% of total perticides (see Table 5). Overall effectiveness of street sweeping can be increased to 75% if two consecutive cleaning cycles are conducted.[14] Subsequent passes remove less of the remaining mass; although overall effectiveness does approach 100 percent as the number of passes increases, the increased effort required to achieve this removal suggests limiting sweeping to three of less consecutive passes.

"No parking" regulations must be enforced to ensure effectiveness of a mechanized street sweeping program, as parked vehicles are presently the greatest obstacle to effective street sweeping.

Caveat: Removal efficiency figures must be evaluated with caution. There are currently three procedures for testing sweeping efficiency: in situ street tests, controlled tests and strip tests. Street tests represent real-world conditions. Controlled tests use an artificially applied uniform loading. Strip tests utilize only the main broom on a narrow path of simulant. Because strip testing is easily run, most data on street sweeping efficiency are developed in this manner. However, since strip testing represents almost ideal operating conditions, the effectiveness figures are high for real-world conditions. For example, recent studies have indicated removal efficiencies of 95% for fine materials by the vacuum cleaning method,[1] but these figures are derived from controlled and strip tests, and further data will be required to corroborate these findings under real-world conditions. Figure I presents a comparison of various removal effectiveness figures by type of test conducted.

Table 5

% Sweeper Efficiency	Particle Size (μ)	Total Solids: % Size Distribution	BOD_5: % Size Distribution	Total Heavy Metals: % Size Distribution	Total Pesticides: % Size Distribution
79	> 2000	24.4	7.4	16.3	0
66	840-2000	7.6	20.1	17.5	16
60	246- 840	24.6	15.7	14.9	26.5
48	104- 246	27.8	15.2	23.5	25.8
20	43- 104	9.7	17.3	27.8	31.7
15	< 43	5.9	24.3	----	----

Source: 14

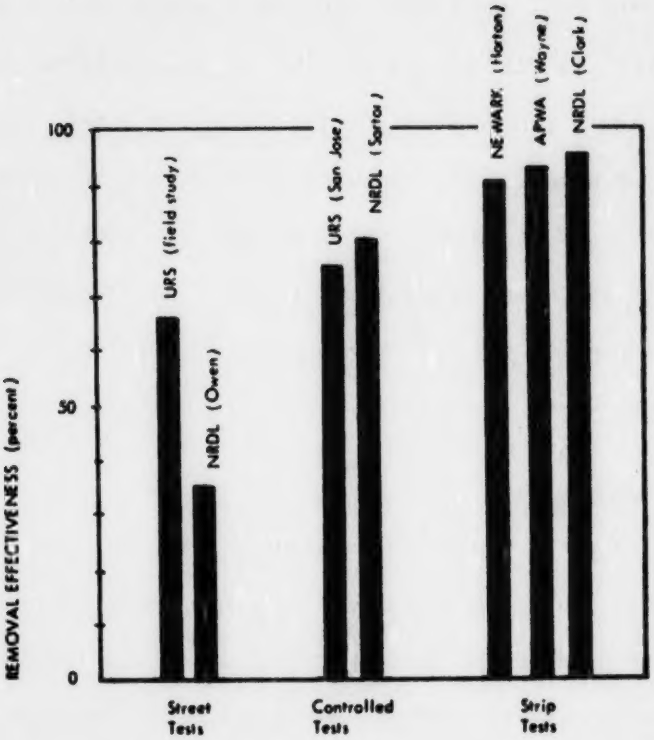


Fig. 1. Comparison of Results from Sweeping Effectiveness Tests Conducted Under Various Conditions: For Dirt/Dust Fraction

Source: 14

Capital costs for street sweepers vary with type of equipment required. The range (in 1975 dollars) is from $21,000-$25,000 for three-wheel vehicles, $32-35 thousand for four-wheel equipment, and $35-40 thousand for vacuum cleaners.[17] Preliminary results from an on-going American Public Works Authority (APWA) study on street cleaning practices in 132 cities in the U.S. and Canada indicate a median figure of $1.20 per capita annual O&M costs ($13.60/ton or cubic yard) for street cleaning.[9] This figure supposedly includes all costs, including water used for dust control, and depreciation. The data were derived from questionnaire responses, however, and the diversity of accounting practices in various municipalities has long been an obstacle in arriving at comparable data. The APWA study, funded by the National Science Foundation, is due for publication in mid-June, 1976.

2. Solid Waste Management

Rather than relying completely on pickup of street litter by street cleaning equipment, convenient location of trash receptacles, increased frequency of trash pickup, and enforcement of anti-litter laws are additional approaches to the problem. Good solid waste management practices, including education of the general public on the pollutional impact of littering, provide significant aesthetic and water pollution control benefits. These benefits, however, are difficult to measure in economic terms.

3. Catch Basin Cleaning

Catch basin cleaning is a third housekeeping technique. While the term "catch basin" is nonspecific and covers a variety of devices, a commonality exists in that catch basins act as simple sedimentation tanks for the removal of coarse solids. However, they do not impact on fine or organic matter, because catch basins are limited by the parameters of turbulence and retention time, as is any sedimentation process. These parameters will obviously vary tremendously with basin sizing. During periods of storm runoff, the simultaneous settling of particulate solids into the catch basin and the resuspension of solids into water flowing from the catch basin make difficult the collection of quantitative data on the performance of catch basins as pollution control devices. Research indicates, however, that "dirty" catch basins exert a significant pollutant load on receiving waters.[14] Basins which are cleaned frequently have a greater capacity to operate at design efficiency and to retain solids and associated pollutants, although, as stated earlier, a high percentage of pollutants are associated with the fine particle sizes that are most difficult to control. Recognizing the difficulty of control of these fine solids and the tendency of catch basins to accumulate organic matter which then decomposes, one research study[14] recommended that

> public works departments give serious consideration to how necessary catch basins are in their particular systems. When a simple stormwater inlet structure would suffice, it is probably desirable to get rid of the catch basin (either by replacing it or by filling it in).

Research on catch basin cleaning in Tulsa in FY 1967-68 and FY 1968-69 indicates that older catch basins are being replaced with "self-cleaning" devices that have direct connection to the storm sewer line and no holding capacity for solids or runoff water. Newer developments in Tulsa do not include catch basins in the street design.

Cleaning of catch basins may be accomplished by four methods: hand, clamshell, eductor or vacuum. The hand or manual method generally consists of bailing out the water and removing the debris with long-handled dippers. The catch basin material is deposited on the street surface, and is then hauled to disposal sites. The clamshell method utilizes a mechanical bucket which, through the use of an hydraulic crane, lifts the solid catch basin material and deposits it into a truck. The merit of this method is its speed of operation. Disadvantages include the difficulty of transferring nonsolid catch basin material without the occurrence of spills and the problem of bucket passage into smaller catch basin inlets. The eductor method of cleaning catch basins uses a large vacuum truck equipped with sewer jet hose to suck material into the tank compartment. These vacuum trucks also double as street flushers. While this method is sanitary due to limited leakage onto street surfaces, large materials in the basin must first be removed manually. Catch basin cleaning through the use of a hose attachment to a vacuum sweeper is a relatively recent alternative that has received limited research. It suggests itself as a cost-effective alternative because of its dual purpose capability.

Costs for catch basin cleaning in various cities are presented in Table 6.

4. Sewer Flushing

Solids deposit in combined sewers has been shown to contribute significantly to the pollutant impact of stormwater overflows.[6,8] These solids, deposited during dry weather periods, are flushed loose during subsequent heavy rainfall. Minimizing the quantity of solids deposited during the dry weather period will reduce the pollution caused by subsequent overflows from combined sewers. Periodic sewer flushing is a means of maintaining lower levels of these deposited solids, by removing

Table 6. CATCH BASIN CLEANING IN CITIES SURVEYED

	Total No. Catch Basins	Frequency of Cleaning	Number Cleaned/ Year	Method	Number of Eductors	Number of Crews	Men/ Crew	Cost, $/Catch Basin
San Jose	N.A.	as required	3,600	Eductor	1	1	2	9.52
Phoenix	3,100	6/yr	18,600	Hand	-	12	2	—
				Eductor	1	2	2	—
Baltimore	32,200	1/yr or as required	about 68,000	Hand	-	6	4	15.00
				Eductor	4	2	3	3.00
Seattle	20,000	1/yr	20,000	Eductor	8	7	2	5.64
Minneapolis	35,000	as required	N.A.	Eductor	1	1	2	N.A.
St. Paul	10,000	as required	N.A.	Hand	-	1	2	15.00
				Eductor	2	1	1	N.A.
San Francisco	50,000	as required	12,000	Eductor	10	8	3	9.12

NOTE: N.A. = Not Available

Source: 14

settled material during dry weather and hydraulically conveying it to the treatment plant.

A 1972 study of combined sewer laterals in Detroit[6] resulted in the development of an engineering basis for periodic sewer flushing of small combined sewer laterals (12- and 18-inch diameters). The cleansing efficiency of periodic flush waves was concluded to be dependent on flush volume, flush discharge rate, sewer slope, sewer length, sewage flow rate and sewer diameter. Slight irregularities in sewer slope and pipe alignment and details of the flush device inlet to the sewer were found insignificant in affecting cleansing efficiencies. A prototype flush station was developed during the project which, when inserted in a manhole, collects sewage from the sewer, retains it, and releases it as a flush wave upon receipt of an external signal. Use of settled sewage rather than clean water as the flushing liquid caused only minor reduction in cleansing efficiency. Table 7 presents the estimated flushing costs and efficiencies (in percent solids removal/day) as a function of the number of flush stations per lateral.

A recent study of Dorchester Bay[10] presents a cost-effective comparison of alternative plans for reducing combined sewer overflows from two metropolitan communities in the Boston area. Controls included periodic sewer flushing. Daily flushing of 100 critical segments reduced total daily predicted solids deposition in 3000 segments by 50%. Table 8 indicates the cost-effectiveness of four programs proposed by the study as compared with two existing proposals. For example, Program IV (including sewer flushing) provides for water quality protection comparable to that

Table 7. ESTIMATED FLUSHING COSTS

Alternate	1	2
Number of flush stations per lateral	2	4
Area per lateral - acres	9	9
Daily solids removal - percent	61	72
Installed cost of fabric flush tanks	$5,556	$11,246
Cost of telemetry and controls	not estimated	
Monthly power cost	$1.95	$4.09
Monthly maintenance cost	$100	$200
Capital cost per acre	$617	$1,250
Monthly maintenance and power cost/acre	$11.32	$22.70

Source: 6

Table 8. PROGRAM SUMMARY

Acceptable Coliform Swimming Standards At:

PROGRAM		South Boston Beaches (3)		Dorchester Beaches (2)		Total Present Value Costs (millions)
		Extreme Std.	Mean Std.	Extreme Std.	Mean Std.	
NEW PROPOSAL						
I	Basic Remedial Program, Sediment Removal in Dorchester Interceptor, elimination of seawater intrusion and small control program in South Boston.*	X	X			5
II	Same as I plus 2 MG Storage in Dorchester	X	X	X		8
III	Same as I plus 11.1 MG storage in Dorchester plus Dorchester flushing program.**	X	X	X	1 of 2+	25
IV	Program I plus: 18 MG storage in Dorchester, Dorchester flushing program** and chlorination of South Dorchester overflows.	X	X	X	X	38
EXISTING PROPOSAL						
V	Old Harbor Plan (South Boston)	X	X			57***
VI	Old Harbor Plan plus Malibu-Tenean Beaches Plan (South Boston and Dorchester)	X	X	X	X	100***

South Boston beaches. Pleasure Bay, L Street, and Carson Beach.
Dorchester beaches: Malibu and Tenean.

* South Boston Program consists of 1 MG storage (4 sites) plus flushing daily 22 critical sections.
** Dorchester flushing program: flushing daily 100 critical section of pipe.
*** Capital costs only.
+ Protection achieved at Malibu Beach.

Source: 10

provided by Program VI, but at roughly 40% of the cost.

5. Deicing Material Controls

A recent study on storage and handling of deicing chemicals indicates that approximately 9 x 10^6 tons of salt and other deicing chemicals are purchased each year by highway and street departments and other organizations in the U.S., to the tune of $140,000,000. From the time they are mined until they reach highway maintenance yards for subsequent application to streets, these salts pass through several rounds of handling and storage. At any of these storage points, exposure to wind or rain will dissipate salt into the environment. In an area with 40 inches of precipitation per year, a salt pile left exposed for six months would lose 5% of its volume,[13] not including losses to wind. A 500 ton salt pile would lose 25 tons under these conditions, an amount sufficient to pollute approximately 15 million gallons of water to the 250 milligrams per liter chloride maximum recommended for drinking water supply by the U.S. Public Health Service. Special additives within most highway salts may create pollution problems[5,13] even more severe than chloride pollution; sodium ferrocyanide, used to minimize salt stock caking, is water soluble and will generate cyanide in the presence of sunlight.

While the direct cost to a highway department of losing 25 tons of salt is only about $400-500, there are additional indirect costs due to corrosion damage to equipment, to cars, to bridges, and to adjacent telephone cables, water distribution lines and other utilities, in addition to environmental degradation. These indirect costs are difficult to assess because the effects of salt runoff are dispersed and because a monetary value for pollution of drinking water is difficult to ascertain.

To prevent these direct and indirect costs, the study[13] recommends the use of fixed storage as a cost-effective alternative. It states that, over a period of 10 to 40 years, the value of salt saved by protection from the weather is sufficient to offset much of the capital cost of a storage building. The "beehive," a structure free of posts, pillars or poles, will store up to 5000 cu. yd. of sand-salt. Costs are reported at approximately $5.00-$6.00/ton stored.

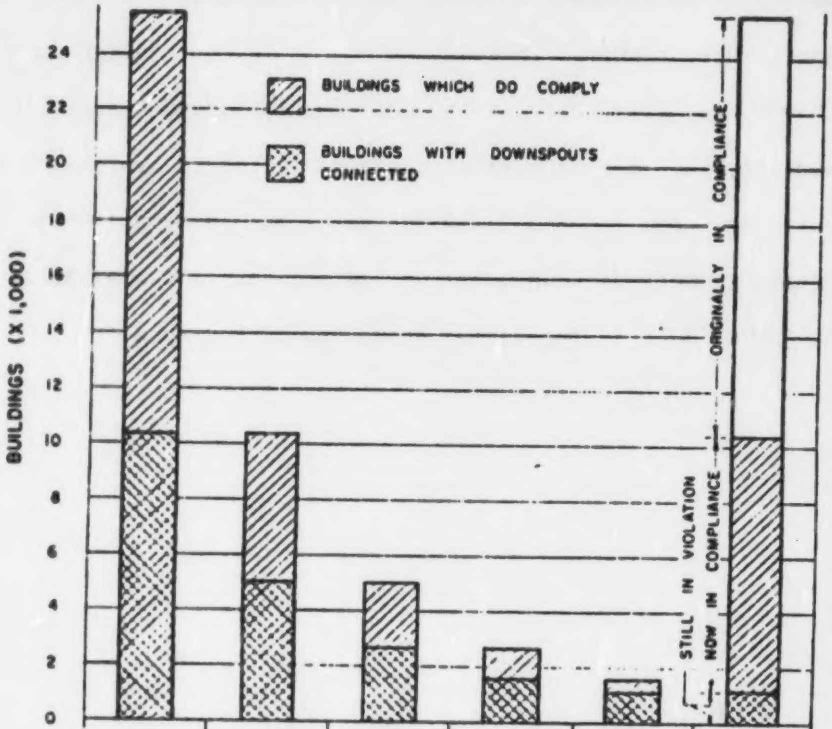
Reduced application of deicing materials is a second alternative for minimizing environmental problems. Salts are sometimes applied in anticipation of snow, based on weather forecasts. Frequently, no snow follows application.

Frequent calibration of salt spreaders and better training of equipment operators are also suggested as techniques to minimize environmental degradation from deicing material use.

6. Disconnection of Roof Leaders

In many U.S. cities roof leaders are still connected to sanitary and combined sewers. During heavy rainfall, the runoff from roof surfaces enters the sewers through these leaders, and augments the flow. Disconnection of leaders from these sewers helps to reduce the peak loading at treatment plants during storm events. With disconnection, runoff from roof drains flows over lawns and sidewalks, where a portion of the flow either ponds or is absorbed by pervious surfaces. In separate sewer areas, the flow eventually enters the storm sewer system through curb or street inlets. In areas served by combined sewers, runoff from disconnected roof leaders often enters the same system from which the leaders were disconnected, but reduces peak loading through flow attenuation.

A 1969 article in the Journal of the Water Pollution Control Federation[12] reports the results of a roof drain disconnection program in Springfield, Illinois. This program, conducted from April 1966 to April 1968, resulted in a 90% reduction in roof leader connections (see Figure 2). Total cost of the program, including survey and inspection, was $45,010. A breakdown of costs indicates an average of $1.67 per building inspected and $2.50 per downspout removed. Costs to property owners to correct downspouts varied from as little as $5 to as much as $50 or $100 if the gutter needed to be resloped.



	1st INSPECTION	2nd INSPECTION	3rd INSPECTION	4th INSPECTION	5th INSPECTION	OVERALL CAMPAIGN
INSPECTIONS	25,527	10 279	4,969	2,710	1,629	25,527
NO. CONN.	10,279	4,969	2,710	1,629	1,190	1,190
% CONN.	40.3	19.5	10.6	6.4	4.7	4.7

This bar graph shows the overall campaign results.

FIGURE 2. CUMULATIVE RESULTS OF DOWNSPOUT REMOVAL PROGRAM

Source: 12

Evaluation of Housekeeping Techniques

We have briefly run through various housekeeping techniques for urban runoff management in developed areas. Now I propose that we step through a very simple methodology for comparative evaluation of these techniques on socio- and cost-effective bases. We should begin with a cautioning note that it is the methodology that we are developing, not each individual element. Therefore, the reader may quibble with matrix entries, recognizing the subjectivity of the author in entering them. The methodology itself, however, may be applied by the reader with his own substituted values.

1. Define Beneficial Uses of Water

The first step in the evaluation of any set of water quality alternatives is the determination of beneficial uses. Table 9 is a matrix of beneficial uses and the parameters which must be controlled in order to protect these uses. Obviously, the body of water used strictly for navigation will require a lesser degree of controls than that which serves as an area's drinking water supply.

2. Define Techniques to Control Parameters

Once beneficial uses and their controlling parameters have been determined, techniques to control these parameters may be defined. Table 10 is a simplified matrix of housekeeping techniques and the parameters upon which they impact. The matrix is simplified because it requires several qualifications. While it indicates the high-sufficient-low effectiveness of techniques on various parameters, the columns are not strictly comparable.

Table 9

Beneficial Uses

	Water Supply	Contact Recr.	Prop. of Fish	Navigation	Aesthetics
O_2 demand	x	x	x		
Suspended solids	x	x	x	x	x
Heavy metals, toxics	x	x	x		
Pathogens	x	x	x		
Nutrients	x	x			
Debris	x	x		x	x

Table 10

	O_2 demand	Suspended solids	Heavy metals, toxics	Pathogens	Nutrients	Debris
street cleaning		[TS]				
broom	✓	✓	✓	-	✓	+
vacuum	✓	+	+	-	+	+
catch basin cleaning	-	✓	✓	-	✓	+
sewer flushing	-	✓	✓	-	✓	+
deicing material control	-	-	+	-	-	-
improved trash collection	-	-	-	-	-	+
roof leader disconnection	-	-	-	-	-	-
treatment (secondary)	+	+	+	+	+	+

For example, while vacuum cleaning rates high in removal of solids, these efficiencies reflect only those solids from street surfaces, not a total land area removal, and are thus not comparable to the high solids removal of treatment. What the matrix does indicate, however, is that, with a definition of beneficial uses, housekeeping techniques can be applied toward abating or reducing pollution impacting these uses. While the exact quantities of pollutants from specific land uses which reach receiving waters have not been defined, removal of pollutants from land surfaces will decrease the aggregate amount of pollutants available to enter the receiving waters.

The matrix also indicates that, for certain uses (such as water supply or contact recreation, where pathogen control is required), complete control of parameters to protect these uses is not achievable through the implementation of housekeeping techniques alone. This is a relevant point to keep in mind now and throughout any evaluation of techniques -- no one technique will be the panacea for all urban runoff problems.

3. Factor in Public Acceptance/Political Implementation as A Function of Socio-Economic Considerations

We have now determined our beneficial uses, and we have defined techniques to protect these uses. Now -- all we require to ensure water quality is to inform the public that we are instituting parking regulations on all commercial streets for optimal efficiency of our vacuuming equipment and that they will need to park elsewhere, that we are going to scrap the "bare pavement" policy this winter to protect our streams from chloride runoff, and that all property owners, at their own time and expense, must disconnect their roof leaders.. **Cost-effectiveness** aside, any technique which threatens traditional perceived social benefits will be difficult to implement because it will be fought all the way. Table 11 clearly indicates that those housekeeping techniques which are most acceptable are those which do not threaten perceived social benefits and which have been traditionally practiced, regardless of cost. I stress perceived benefits, because, as in the example of deicing material controls, the American public expects bare pavements at the tradeoff of corrosion to automobiles and bridges as well as negative environmental impacts. It also perceives improved trash collection practices as beneficial for both aesthetic and health reasons, and the benefit is doubly perceived because, unlike chloride pollution, the impact is both direct and visible.

Conclusion

In conclusion, then, let us combine quality and quantity controls, social values and costs to obtain a rough composite evaluation of each technique. Similar matrices have been developed for evaluation of stormwater controls for the Newcastle County, Delaware 208 area.[16] The pluses, checks and minuses of Table 12 are, of course, a convenient notation, qualified by the subjectivity of their author. Again, comparison of column entries must be qualified; some techniques, such as street cleaning, impact only a small percentage of total land use, and are thus not strictly comparable with treatment efficiencies and costs. In addition, a composite comparison of techniques (row-by-row comparison) must recognize that the evaluative parameters are not of equal impact in selection of techniques, so that we cannot merely average the minuses and pluses over the row to derive a composite ranking of techniques. Any attempt to do so must

Table II

	Public acceptance	Perceived social benefit	Tradition	Costs		Comments
				Cap.	O&M	
street cleaning						
broom	✓	✓	✓	✓	✓	
vacuum	-	-	-	✓	+	no parking regs
catch basin cleaning	✓	✓	✓	✓	-	
sewer flushing	✓	✓	✓	✓	-	
deicing material control	-	-	-	✓	✓	bare pavement policy
improved trash collection	+	+	+	✓	-	aesthetics, health
roof leader disconnection	-	-	-	+	+	private cost, concept difficult to explain
treatment (secondary)	✓	✓	✓	-	-	perceived as essential, but "not next to my property"

Table 12

	O_2 demand	Suspended solids	Heavy metals, toxics	Nutrients	Pathogens	Debris	Public acceptance	Perceived social benefits	Costs	
									Capital	O&M
street cleaning										
broom	✓	✓	✓	✓	-	+	✓	✓	✓	✓
vacuum	✓	+	+	+	-	+	-	-	✓	+
catch basin cleaning	-	✓	✓	✓	-	+	✓	✓	✓	-
sewer flushing	-	✓	✓	✓	-	+	✓	✓	✓	-
deicing material control	-	-	✓	-	-	-	-	-	✓	✓
improved trash collection	-	-	-	-	-	+	+	+	✓	-
roof leader disconnection	-	-	-	-	-	-	-	-	+	+
treatment (secondary)	+	+	+	+	+	+	✓	✓	-	-

recognize the subjectivity inherent in such an approach. What Table 12 does provide, however, is a simplified overview of alternative housekeeping techniques. It indicates cost-effectiveness and public acceptability, and thus highlights those parameters which may stand in the way of the effective implementation of specific techniques. A first-cut analysis of this sort can serve to eliminate (or, at least, to qualify) inoperative techniques, and can [illegible] aid in the selection of cost-effective alternatives for control of stromwater runoff problems in urbanized areas.

References

1. AVCO Economic Systems Corporation, *A Multi-Phasic Component Study To Predict Storm Water Pollution From Urban Areas*, report to *Office of Water Resources Research*, Department of Interior, December 1970.

2. AVCO Economic Systems Corporation, Storm Water Pollution From Urban Land Activity, report to Federal Water Quality Administration, Department of Interior, July 1970.

3. Black, Crow & Eidness, Inc. and Jordan, Jones & Goulding, Inc., *Non-Point Pollution Evaluation Atlanta Urban Area*, report to Savannah District Corps of Engineers, May 1975.

4. Black, Crow & Eidness, Inc. and Jordan, Jones & Goulding, Inc., Study and Assessment of the Capabilities and Cost of Technology for Control of Pollutant Discharges from Urban Runoff, report prepared for the National Commission on Water Quality, October 1975.

5. Field, Richard et. al, "Water Pollution and Associated Effects from Street Salting," *J. Env. Eng. Div., ASCE*, Vol. 100, No. EE2, April 1974.

6. FMC Corporation, *A Flushing System For Combined Sewer Cleansing*, 11020 DNO, March 1972.

7. Lager, John A., "Stormwater Treatment: Four Case Histories," *Civil Engineering - ASCE*, December 1974.

8. Lager, John A. and Smith, William G., *Urban Stormwater Management and Technology: An Assessment*, EPA 670/2-74-040, December 1974.

9. Murphy, William, American Public Works Association, telephone conversation with, November 1975.

10. Pisano, William, "Cost Effective Approach For Combined and Storm Sewer Clean-up," paper presented at EPA Urban Stormwater Management Seminars, November-December 1975.

11. Pitt, Robert E. and Amy, Gary, *Toxic Materials Analysis of Street Surface Contaminants*, EPA-R2-73-283, August 1973.

12. Poertner, Herbert G., *Practices in Detention of Urban Stormwater Runoff*, Office of Water Resources Research, June 1974.

13. Richardson, David L. et. al, *Manual For Deicing Chemicals: Storage and Handling*, EPA-670/2-74-033, July 1974.

14. Sartor, James D. and Boyd, G. B., *Water Pollution Aspects of Street Surface Contaminants*, EPA-R2-72-081, November 1972.

15. Shubinski, Robert P., "Concepts of Urban Runoff Control," Management of Urban Storm Runoff, ASCE, OWRR C-4048, May 1974.

16. Turner, Collier & Braden, Inc., Structural and Non-Structural Techniques Summary for Management and Control of Stormwater Pollution, draft report prepared for 208 Planning Agency, Newcastle County, Delaware, November 1975.

17. Telephone conversations with various equipment manufacturers, November 1975.

QUESTIONS AND ANSWERS

(Following paper by Kathie Adgate, "Land Management Techniques for Stormwater Control in Developed Urban Areas".)

Question: Will you discuss land use planning in relation to housekeeping techniques?

Adgate: I see a difference between land use and land management planning. Land use planning would define the uses permitted; whereas, land management planning would be that which helps one manage those uses which are already in place. We have a distinct dichotomy between developed and developing areas. The land uses are already defined in a developed area, so you don't have the alternatives for land use planning there. Our next speaker will discuss some of the land management practices for developing areas. This is the place where land use planning could be important.

Question (Robert L. Braun, Idaho Dept. of Health & Welfare): I would like to know your feelings on street-washing techniques--street-washing versus street-sweeping.

Adgate: I believe that the literature indicates that street washing merely redistributes the load and puts it back into the system. In Washington, D.C., I had an interesting conversation with an operator of street washing equipment. I asked him "exactly what do you do?" He said "I just wash the dirt off the street into the Potomac River". I think that street washing has a limited quality benefit.

Question: How do you relate Table No. 8 that you showed to cost-effectiveness? It seems to me that it is subjective and that there is no hard data to work with.

Adgate: That's a good point. A few studies have been done on housekeeping techniques, but we really don't have much good data.

Comment (Andrew Waldo, EPA, Washington, D.C.): You might mention that we (EPA) have been working a good deal on studying the cost-effectiveness of some of these various techniques. We have been surveying the literature to determine the costs of various techniques and compare costs, in a cost-effective manner. The whole point is establishing the impact on water quality. We are coming up with some of these costs so that we can compare them and go to a level of higher sophistication.

Comment (Michael Seaman, Snohomish County, Washington): I disagree with you when you say that land use planning doesn't have a place in a developed area, because that assumes that cities don't change. But cities are dynamic and we are involved every day in making land use planning decisions that may have impacts on water quality. I had hoped that EPA would be able to give us the same kind of guidance on developed areas that you are presenting today on developing areas.

Adgate: I think that your point is well taken for redevelopment in an urban area.

Question (Steve Sowby, Mountainland Assoc. of Govts., Provo, Utah): Do you really think that we can sell these housekeeping techniques to the public in the name of water quality? In past years, they have been sold in the name of aesthetics and beautiful, clean cities. My other question is--where do you flush the sewers to when you flush them?

Adgate: In response to your first question, we can't merely propose a cost-effective approach and expect the public to buy it. I don't necessarily think that you can sell it on water quality benefits. You must sell a systems approach as a package--including such things as local flood control, quality aspects, health aspects and others. I don't think that you can sell it strictly for water quality purposes,and it would be very difficult to implement. Although there may be very low capital costs and O & M costs associated with some of the techniques, people are not necessarily going to buy it just for that reason. You will also have to show them why. In response to your question on sewer flushing, I believe that Dr. Pisano will answer your question today when he presents his paper on sewer cleanup.

Comment (Douglas B. Cargo, Univ. of Texas, Dallas): I think that paying more attention to the solid waste problem could reduce floatables considerably in stormwater discharges. It is easier to implement and people perceive it better in terms of aesthetics.

Subject: LAND MANAGEMENT TECHNIQUES FOR DEVELOPING AREAS *

Introduction: TO GIVE YOU SOME BACKGROUND FOR THE CAPABILITY OF SCS TO SPEAK ON THIS SUBJECT, I WOULD LIKE TO POINT OUT WHAT THE SOIL CONSERVATION SERVICE (SCS) IS, AND HOW WE PROVIDE ASSISTANCE TO THE PUBLIC THROUGH SOIL CONSERVATION DISTRICTS. I WILL POINT OUT SOME OF THE PROBLEMS IN DEVELOPING AREAS AND THEN DISCUSS SOME OF THE LAND MANAGEMENT TECHNIQUES WHICH CAN MINIMIZE EROSION AND SEDIMENT PROBLEMS. THEN I WOULD LIKE TO DISCUSS VERY BRIEFLY SOME OF THE TOOLS AND REFERENCES THAT SCS TECHNICIANS USE IN PROVIDING ASSISTANCE ON THESE LAND MANAGEMENT TECHNIQUES.

(1) Opportunities in conservation

*MUCH CAN BE DONE TO IMPROVE LAND MANAGEMENT TO REDUCE EROSION AND SEDIMENTATION IN URBAN AREAS. WE IN THE SOIL CONSERVATION SERVICE CAN HELP.

(2) Mountain subdivision

*THE SOIL CONSERVATION SERVICE (SCS) GIVES TECHNICAL ASSISTANCE TO INDIVIDUALS, GROUPS, ORGANIZATIONS, CITIES AND TOWNS, AND COUNTY AND STATE GOVERNMENTS IN REDUCING THE COSTLY WASTE OF LAND AND WATER RESOURCES AND IN PUTTING TO GOOD USE THESE NATIONAL ASSETS. OUR OBJECTIVE IS PROPER USE AND TREATMENT OF THE LAND IN HARMONY WITH ITS CAPABILITY AND NEEDS.

---

* Slide talk presented by L. Duane Bartee, Deputy State Conservationist, SCS, at the December 2-4 EPA Seminar, Cosmopolitan Hotel, Denver, Colorado

NOTE: A brief description of each slide is given in the margin opposite the narrative.

(3) Reviewing soils map	*OUR TECHNICAL STAFF DIAGNOSES RESOURCE PROBLEMS AND PRESCRIBES SAFE USE AND TREATMENT. THE TECHNICAL STAFF INCLUDES SOIL SCIENTISTS; ECONOMISTS; AGRICULTURAL, IRRIGATION, HYDRAULIC, DRAINAGE, AND CARTOGRAPHIC ENGINEERS; AND SPECIALISTS IN AGRONOMY, BIOLOGY, FORESTRY, PLANT MATERIALS, RANGE MANAGEMENT, GEOLOGY, AND SEDIMENTATION.
(4) Conservationist with homeowners	*LAND USERS AVAIL THEMSELVES OF THESE TECHNOLOGIES THROUGH THE ONSITE ASSISTANCE THEY RECEIVE FROM A SPECIALIST DEVELOPED BY SCS--THE SOIL CONSERVATIONIST. HE IS A PROFESSIONAL SKILLED IN APPLYING THE COMBINED METHODS OF THE PHYSICAL, BIOLOGICAL, AND SOCIAL SCIENCES TO PRACTICAL PROBLEMS OF LAND USERS.
(5) Soil sample	*THE SOIL CONSERVATIONIST HELPS LAND USERS TO PLAN FOR EACH LAND UNIT AS A WHOLE, INTEGRATING ALL ASPECTS OF LAND USE AND TREATMENT. HE WORKS ON THE PRINCIPLE THAT SOIL, WATER, PLANT, AND ANIMAL RESOURCES CANNOT BE EFFECTIVELY USED OR MANAGED SEPARATELY BUT ARE INTERDEPENDENT AND MUST BE DEALT WITH AS A WHOLE.
(6) SCS symbol and district sign	*SCS WAS ESTABLISHED IN THE U.S. DEPARTMENT OF AGRICULTURE (USDA) BY THE CONGRESS IN 1935 TO PLAN AND CARRY OUT A NATIONAL PROGRAM TO CONSERVE AND DEVELOP OUR SOIL AND WATER RESOURCES. WE DO THIS THROUGH A COOPERATIVE EFFORT WITH SOIL CONSERVATION DISTRICTS.

(7) District map	*SOIL CONSERVATION DISTRICTS ARE LOCAL UNITS OF STATE GOVERNMENT. THEY ARE RESPONSIBLE FOR THE SOIL AND WATER AND RELATED RESOURCE CONSERVATION PROGRAM IN THEIR AREA. IN SOME STATES THEY GO BY DIFFERENT NAMES, SUCH AS: CONSERVATION DISTRICTS, SOIL AND WATER CONSERVATION DISTRICTS, AND NATURAL RESOURCE CONSERVATION DISTRICTS.
(8) District meeting	*THESE DISTRICTS KEEP THE CONSERVATION PROGRAM RESPONSIVE TO LOCAL NEEDS. DISTRICT SUPERVISORS ARE ELECTED OFFICIALS WHO PLAN AND DIRECT THE CONSERVATION PROGRAM. THROUGH COOPERATIVE AGREEMENTS, THEY CALL UPON SCS AND OTHER FEDERAL, STATE AND LOCAL AGENCIES FOR HELP.
(9) 3,000 conservation districts	*TRADITIONALLY, SCS HAS BEEN THE STRONGEST ALLY OF DISTRICTS IN THEIR CONSERVATION PROGRAM. SCS ASSIGNS PERSONNEL TO WORK WITH SOME 3,000 CONSERVATION DISTRICTS IN THE NATION.
(10) Boating	*THIS CLOSE WORKING RELATIONSHIP HAS PRODUCED SOUND RESULTS ON THE LAND.
(11) Trees	*TODAY, GREEN WOODLANDS COVER ONCE SCARRED HILLSIDES;
(12) Shelterbelt	*NATIVE GRASSES, WINDBREAKS AND SHELTERBELTS HAVE REPLACED A BARREN SHIFTING DUST BOWL;
(13) Contour strips	*COLORFUL CONTOUR STRIPS ADD VARIETY TO THE LANDSCAPE;

(14) Lake	*FARM PONDS, EROSION CONTRAOL DAMS, AND WATERSHED FLOOD PREVENTION STRUCTURES FURTHER PROTECT OUR ENVIRONMENT FROM EROSION AND FLOOD DAMAGE.
(15) Urban conservation	*THIS SAME EFFECTIVE SYSTEM OF COOPERATION CAN BE USED TO PRODUCE WORKING CONSERVATION SYSTEMS IN URBAN AREAS. LET ME SHOW YOU SOME OF THE LAND MANAGEMENT PROBLEMS INVOLVED IN URBANIZING AREAS.
(16) Erosion	*ONE OF THE MAJOR PROBLEMS IS SOIL EROSION.
(17) Bare land	*IN A TYPICAL HOUSING DEVELOPMENT, THE DEVELOPER MAY BULLDOZE BARE AN ENTIRE HILLSIDE. SIX MONTHS TO A YEAR MAY PASS BEFORE HOMES ARE BUILT AND THE HOMEOWNER AGAIN COVERS THE SOIL. WITH THE SOIL GOES HERBICIDE AND INSECTICIDE RESIDUES. IT INCLUDES ELEMENTS FROM PLANT FERTILIZERS.
(18) Gullies	*SOIL EROSION ON A SQUARE MILE OF LAND CAN INCREASE FROM 2 TONS/ ACRE / YEAR ON FARMLAND TO MORE THAN 40 TONS / YEAR ON LAND BEING CONVERTED TO SUBURBAN USES.
(19) Erosion from street runoff	*RUNOFF WATER INCREASES IN URBAN AREAS AS SOIL IS COVERED WITH CONCRETE AND ASPHALT. AS WATER IS CONCENTRATED EROSION BECOMES A PROBLEM.

(20) Concrete outlet	*AN EXAMPLE IS THIS CONCRETE OUTLET ON A TRIBUTARY OF SAND CREEK IN COLORADO SPRINGS.
(21) Eroded drain	*THE STORM DRAIN CONCENTRATED RUNOFF AND CAUSED SEVERE GULLYING AT THE OUTLET.
(22) Eroded ditch	*HEAVY RUNOFF CAN ALSO CARVE AWAY DITCH BANKS.
(23) Sandy hilltop	*WIND EROSION CAN BE A PROBLEM IN URBAN AREAS. HERE THE DEVELOPER BARED AN ENTIRE HILLSIDE. THE SANDY SOIL BLOWS INTO NEIGHBORING YARDS AND HOMES.
(24) Soil blown into drainage	*HOW DOES WIND EROSION AFFECT URBAN STORM WATERS? SEDIMENTS CAN BE CARRIED BY WIND AS WELL AS WATER. THE RESULT IS THE SAME, PLUGGED DRAINAGES.
(25) Sediment	*SEDIMENT, WHETHER FROM WIND OR WATER, IS A MAJOR PROBLEM IN URBAN AREAS.
(26) Mud in street	*SEDIMENT COVERS STREETS,
(27) Mud in reservoir	* REDUCES THE STORAGE CAPACITY OF CITY RESERVOIRS, INCREASES WATER BILLS,
(28) Dredging sediment	*AND REQUIRES TAXPAYER EXPENDITURE TO DREDGE AND CLEAN OUT THE RESERVOIR.

(29) Mud pumped from reservoir	*THE COST OF REMOVING ALL THIS MUD AND RESTORING OUR LAKES AND WATERWAYS IS STAGGERING. OVER A BILLION CUBIC YARDS OF SEDIMENT ARE DEPOSITED IN RESERVOIRS EACH YEAR. THE COST OF DREDGING MAY RUN AROUND $1 A CUBIC YARD, AND OFTEN THERE IS NO PLACE TO SPOIL THE SEDIMENT. BELIEVE ME, IT IS MUCH CHEAPER TO PREVENT EROSION THAN TO DREDGE SEDIMENT.
(30) Flood	*OF COURSE, THE MOST VISIBLE AND OFTEN THE MOST COSTLY DAMAGE IS FLOOD WATER DESTRUCTION. FLOODS ARE NOT ONLY HAZARDOUS TO PROPERTY, BUT TO LIFE ITSELF.
(31) Town in flood plain	*A MAJOR NEED IS FOR BETTER PLANNING TO AVOID DEVELOPMENT IN THE FLOOD PLAIN. WHETHER IT BE AN ENTIRE TOWN,
(32) Caesar's Palace	*OR JUST A RESORT HOTEL, SUCH AS CAESAR'S PALACE, DEVELOPMENT IN THE FLOOD PLAIN IS COSTLY AND HAZARDOUS.
(33) Parking lot	*A PARKING LOT IS NOT QUITE AS BAD A USE OF FLOOD PLAIN,
(34) Flooded park	*BUT PARKS AND RECREATION AREAS ARE THE BEST URBAN USE OF
(34a) Golf Course	*FLOOD AREAS, SUCH AS GOLF COURSES
(35) Attractive homes	*NOW LET'S LOOK AT SOME OF THE CONSERVATION PROGRAMS THAT CAN BE UTILIZED IN URBAN AREAS.

(36) Watershed model	*PROBABLY THE MOST IMPORTANT ONE ADMINISTERED BY SCS IN STORM WATER MANAGEMENT IS PUBLIC LAW 566, THE WATERSHED PROTECTION AND FLOOD PREVENTION PROGRAM.
(37) Eroded watershed	*UNDER THIS PROGRAM SCS CAN HELP LOCAL GOVERNING BODIES PLAN AND APPLY FLOOD PREVENTION MEASURES IN WATERSHED AREAS OF LESS THAN 250,000 ACRES.
(38) Protected watershed	*ONE OF THE FEATURES WHICH MAKES THIS PROGRAM UNIQUE IS THE TREATMENT OF THE ENTIRE WATERSHED WITH CONSERVATION MEASURES. THE IDEA IS TO CATCH AND HOLD AS MUCH WATER AS POSSIBLE WHERE IT FALLS. DAMS AND CHANNEL IMPROVEMENTS ARE THEN USED IN ADDITION AS NEEDED.
(39) Swamp	*SOME PRACTICES THAT CAN BE USED TO REDUCE URBAN DAMAGE INCLUDE THE RETENTION OF LOWLANDS OR SWAMPS FOR OPEN SPACE,
(40) Dam	*CONSTRUCTING SMALL RETENTION DAMS WITH WATER STORAGE CAPACITY FOR RUNOFF PERIODS,
(41) Lake	*THE ENLARGEMENT OF PONDS AND PITS,
(42) Terrace	*AND THE BUILDING OF TERRACES,
(42a) Diversion terrace	*DIVERSIONS, GRASSED WATERWAYS, CONCRETE
(43) Concrete spillway	*CHUTES AND OTHER DEVICES TO MOVE WATER SAFEY OVER THE LAND.

(44) Channel improvement	*RESERVOIR SITES ARE DIFFICULT TO FIND IN URBAN AREAS. THERE ARE USUALLY SEVERAL HOUSES IN THE MIDDLE OF A GOOD SITE. BUT RESERVOIRS ARE A PART OF THE P.L. 566 PROGRAM, AS ARE CHANNEL IMPROVEMENTS.
(45) Flood	*THE FEDERAL GOVERNMENT PAYS THE COST OF FLOOD PREVENTION MEASURES UNDER P.L. 566. IT IS THE LOCAL RESPONSIBILITY TO OBTAIN LAND RIGHTS AND EASEMENTS.
(46) Flood Hazard	*ANOTHER PROGRAM SCS DEALS WITH IN URBAN AREAS IS THE FLOOD HAZARD AND FLOOD INSURANCE STUDIES.
	IF A COMMUNITY IS INTERESTED IN IDENTIFYING ITS FLOOD PLAINS, SCS WILL ENTER INTO AN AGREEMENT TO DO A FLOOD PLAIN STUDY.
(47) Map	*WE ALSO CONDUCT RIVER BASIN STUDIES WHICH PROVIDE MUCH VALUABLE INFORMATION FOR COMMUNITY PLANNING AS IT APPLIES TO SOIL, WATER AND RELATED RESOURCES.
	IN COLORADO, WE HAVE COMPLETED RIVER BASIN STUDIES FOR THE WHITE, YAMPA, GUNNISON, DOLORES, SAN JUAN COLORADO TYPE IV's, COLORADO RIVER TYPE I.
(48) General soil map	*SOIL SURVEYS ARE ALSO USEFUL TO LAND USE PLANNERS AND ALL LAND USERS. WE CONDUCT A NATIONAL/COOPERATIVE SOIL SURVEY PROGRAM WHICH IS VERY USEFUL TO PLANNERS.

(49) Aerial photo map	*SOIL SCIENTISTS IDENTIFY DIFFERENT SOIL PROPERTIES AND LOCATE THE DIFFERENT SOILS ON AN AERIAL PHOTO MAP. SOIL SURVEYS INDICATE AREAS THAT HAVE BEEN SUBJECT TO FLOODING.
(50) Soil pit	*SOME OF THE SOIL PROPERTIES IDENTIFIED INCLUDE SLOPE, TEXTURE, PERMEABILITY, SOIL DRAINAGE, FLOOD HAZARD, DEPTH TO WATER TABLE,
(51) Seasonal wetness	*SEASONAL WETNESS, DEPTH TO BEDROCK, ERODIBILITY, LOAD BEARING CAPACITY,
(52) Shrink-swell	*SHRINK-SWELL CHARACTERISTICS AND CORROSIVITY.
(53) Grass study	*VEGETATIVE STUDIES DONE BY SCS ARE ALSO USEFUL IN HELPING DETERMINE WHICH TYPES OF VEGETATION WILL GROW BEST TO REVEGETATE DISTURBED LANDSCAPES.
(54) Revegetated slope w/retaining wall	*SEVERAL IMPORTANT THINGS CAN BE DONE IN URBAN CONSTRUCTION SITES TO REDUCE EROSION AND RUNOFF.
(55) House in trees	*ONE PRINCIPLE THAT NEEDS TO BE ENCOURAGED IS TO PRESERVE VEGETATION AS MUCH AS POSSIBLE. IT IS POSSIBLE TO CARVE OUT SPACE FOR A HOUSE WITHOUT REMOVING ALL THE TREES AND GRASS IN THE VICINITY.

(56) **Wheatgrass, temporary cover**	*IF AN AREA IS LEVELED AND BARED, THE DEVELOPER SHOULD SEED IT BACK TO A QUICK GROWING ANNUAL COVER.
(57) **Roadside net**	*FRESHLY DISTURBED AREAS CAN BE PROTECTED WITH MULCH.
(58) **Sod** (59)	*SODDING, OF COURSE, IS A GOOD WAY HOMEOWNERS CAN REDUCE URBAN RUNOFF.

SCS USES A NUMBER OF TECHNICAL REFERENCE DOCUMENTS, BUT I WOULD LIKE TO DISCUSS VERY BRIEFLY TWO OF THESE -- "THE UNIVERSAL SOIL LOSS EQUATION" - AND THE "FIELD OFFICE TECHNICAL GUIDE." THE EQUATION IS STATED AS: $A=RKLSCP$.

THE UNIVERSAL SOIL LOSS EQUATION IS A PROCEDURE FOR ESTIMATING SOIL-LOSS UNDER DIFFERENT CONDITIONS. SOIL LOSS , A, IS IN TONS/AC/YEAR - THE CONTRIBUTING FACTORS ARE:

1) RAINFALL CHARACTERISTICS -- R
2) SOIL ERODIBILITY (% SAND, SILT, CLAY): O.M.; STRUCTURE, PERMEABILITY -- K
3) SLOPE (% AND LENGTH) -- S and L
4) CROPPING MANAGEMENT - FALLOW, HIGH RESIDUE, MULCHING, GRASS, ETC. -- C
5) CONTROL PRACTICES - (HOW THE SOIL TILLED) -- P

LET ME SAY: RAINFALL IS A GIVEN FACTOR FOR A SPECIFIC LOCATION. THERE IS NOT MUCH CAN BE DONE ABOUT SOIL ERODIBILITY CHARACTERISTICS - THEREFORE MANAGEMENT IS GENERALLY AIMED AT THE LAST THREE.

(60) Bare site

*WE'LL DISCUSS HOW THIS BARE STIE MIGHT BE TREATED

(61) Soil Loss Table

*THE TABLE SHOWS THE PREDICTED SOIL LOSS FOR THE EXAMPLES SHOWN:

COVER	TON/AC/YR
BARE SOIL	40
RYE GRASS	4
MULCH	.8
GRASS SOD	.4

(62) 5 Sections of Technical Guides

A BRIEF WORD ABOUT "FIELD OFFICE TECHNICAL GUIDES." THIS IS A DOCUMENT DEVELOPED TO PROVIDE A TECHNICAL REFERENCE FOR HANDLING SOIL, WATER AND RELATED RESOURCE PROBLEMS IN A GIVEN LOCATION. THE TECHNICAL GUIDE CONTAINS 5 SECTIONS:

SECTION I: GENERAL REFERENCE MATERIALS

GENERALLY INCLUDES HANDBOOKS AND MANUALS, GENERAL SOILS MAPS, PUBLISHED SOIL SURVEYS, RECREATION POTENTIAL APPRAISALS, LAND USE, LAND OWNERSHIP, PROJECT BOUNDARIES, FLOOD PLAINS, SEDIMENT SOURCES, WILDLIFE HABITAT POTENTIAL, AND OTHER RESOURCE, DEMOGRAPHIC, AND RELATED DATA.

SECTION II: SOIL AND SITE INFORMATION

SOIL SURVEYS ARE INTERPRETED FOR THE MAJOR USES IN THE FIELD OFFICE AREA. SOME CHARACTERISTICS ARE IDENTIFIED AND INTERPRETIVE GROUPINGS ARE MADE SUCH AS WOODLAND SUITABILITY GROUPINGS AND RANGE SITE DESCRIPTIONS WITH RANGE CONDITIONS DESIGNATED. THE ALMOST UNIVERSAL USE OF SCS-SOILS-5, "SOIL SURVEY INTERPRETATIONS," FOR PROVIDING ALTERNATIVE USES AND TREATMENT, HELPS TO ASSURE UNIFORMITY IN OUR TECHNICAL QUALITY.

SECTION III: RESOURCE USE AND MANAGEMENT SYSTEMS

ALTERNATIVE CONSERVATION USES AND TREATMENTS IN KEEPING WITH OUR OBJECTIVES OF (1) QUALITY IN THE RESOURCE BASE, (2) QUALITY IN THE STANDARD OF LIVING, AND (3) QUALITY IN THE ENVIRONMENT ARE EXPLORED AS RELATED TO VARIOUS RESOURCE MANAGEMENT SYSTEMS. MOST AREAS ARE SUITABLE FOR TWO OR MORE ALTERNATIVE USES AND NUMEROUS CONSERVATION TREATMENTS, HENCE, WE DEVELOP AND PROVIDE APPROPRIATE ALTERNATIVE COMBINATIONS TO DECISION MAKERS.

SECTION IV: PRACTICE STANDARDS AND SPECIFICATIONS

THE MINIMUM LEVEL OF ACCEPTABLE QUALITY FOR THE PRACTICES USED IS ESTABLISHED ALONG WITH THE MINIMUM REQUIREMENTS FOR INSTALLATION OF SUCH PRACTICES.

SECTION V: COST-RETURN INFORMATION

SUITABLE COST-RETURN INFORMATION IS GATHERED AND DOCUMENTED TO MEET THE FIELD OFFICE NEEDS. GENERALLY THREE KINDS OF DATA ARE

NEEDED: (1) YIELD ESTIMATES FOR CROPS GROWN UNDER VARIOUS MANAGEMENT LEVELS, (2) COSTS OF CONSERVATION TREATMENT, AND (3) USUAL PRODUCTION COSTS AND RETURNS FOR A RANGE OF YIELD LEVELS.

THESE DOCUMENTS ARE UNDOUBTEDLY THE BEST REFERENCES FOR TREATING EROSION PROBLEMS IN MOST ANY LOCATION IN THE UNITED STATES.

IF YOU HAVE NEED FOR THIS TYPE INFORMATION, WE INVITE YOU TO CONTACT ONE OF THE NEARLY 3,000 FIELD OFFICES ACROSS THE COUNTRY.

THANK YOU FOR PERMITTING ME TO DISCUSS-WHO WE IN SCS ARE, HOW WE ASSIST THE PUBLIC, SOME OF THE PRINCIPLES AND TECHNIQUES IN MINIMIZING THE EFFECT OF URBAN STORM WATER AND TO REFLECT ON SOME OF THE CONSERVATION REFERENCES AND HOW THEY ARE USED.

IF YOU HAVE QUESTIONS, I WOULD BE HAPPY TO TRY TO ANSWER THEM AT THE APPROPRIATE TIME.

QUESTIONS AND ANSWERS

(Following Duane Bartee's paper "Land Management Techniques for Developing Areas")

Question (Daniel Straub--Kahenkamp, Sachs, Wells and Assoc.): I believe that most of your concepts of retaining water at the point where it falls is very sound and practical; however, it runs counter to some of the traditional engineering practices of collecting and transporting storm water to treatment or disposal points. Can you point out some of your experiences and local acceptance in urban areas or developing suburban areas?

Bartee: Most of our experience is with smaller communities. The principles are very similar; however, we usually do not think of treatment. Generally, what's involved is transporting runoff in some safe manner that doesn't carry solids and sediment with it.

Straub: I am more interested in your comments on retaining water on the site where it falls as rain, and collection in swales instead of pipes.

Bartee: We encourage maintaining the natural watercourses in these developing areas, whenever possible.

Straub: We found that local acceptance by people who must approve such on-site retention methods is difficult to get. You must have a lot of strong backup information. Have you found much local resistance?

Bartee: No. The principles are sound. It is a matter of getting them communicated.

Comment (Athayde, EPA): I would like to answer that question on public acceptance. In the Washington, D.C. area--in Fairfax County, Virginia, and Montgomery County, Maryland--the local governments have programs for holding the water where it falls and attenuating runoff flows. As far as public acceptance is concerned, Fairfax County has proceeded without having an ordinance. They merely adopted a policy and got the land developers and contractors to do what they wanted them to do. This is one area of the country where I was amazed to see hay bales around construction sites (for trapping silt in runoff). Montgomery County is trying to implement the State of Maryland law on erosion control. They have a program where they require developers to provide detention basins on or around the construction site to contain the runoff. I think that Mr. Bartee's presentation points out that we have to consider flood control and erosion control as well as water quality.

Question (Dennis Maroney, Karcich & Weber Engineers, Colorado Springs, CO.): My question relates to the Universal Soil Loss Equation. In using the equation, you generate sediment loads from a given area on an annual basis. Some work has been done to bring that down to an individual storm occurence and relating it to a hydrograph. Are you aware of that work?

Bartee: No. But, I wouldn't be surprised to find that the Agricultural Research Service, and possibly some SCS hydrologists, and scientists, worked on that.

Comment (Richard Field, EPA): I wish to comment on the last question. People at the University of Florida have endeavored to use the Universal Soil Loss Equation on a per-storm basis with some success in verification, but I wouldn't wholly endorse it at this point.

Comment (John Promise, North Central Texas COG): In responding to that question, OKI has been doing work and EPA is distributing information concerning their work. They have applied the Universal Soil Loss Equation for specific events as well as for an annual average.

Question (Michael Seamen, Snohomish County, Washington): You mentioned many practices for conservation of water quality, but they primarily relate to site preparation and site managing. I am sure that there are other practices, for developing areas, that could be worked into building codes,such as flat roofs for storage, ground infiltration of rainwater from roofs, et cetera. Do you know of any techniques like that or any documents that have been written?

Bartee: I don't know of any. I think all these techniques might be useful, but I am not sure of what effect they may have, percentagewise, in controlling the total runoff.

Comment (Herbert G. Poertner, Engineering and Research Consultant, Bolingbrook, Illinois): A publication which I authored addresses your area of interest. It covers urban stormwater detention and describes many applications of temporary storage of excess runoff on roofs, parking lots, and in basins on ground surfaces. It also gives examples of discharge of water from rooftops of buildings into trenches filled with rock and granular material to provide stormwater storage voids and reduce the flow rate of the excess stormwater into the downstream drainage system. An example of this is found at the Cabin John Tennis Club in Rockville, Maryland. The title of the final report of the study that I made is "Practices in Detention of Urban Stormwater Runoff". I donated my manuscript to the American Public Works Association so that they could publish it and make it widely available. The APWA also provided assistance in gathering information and reviewing the manuscript, as did many other organizations and individuals. The study was partially financed by the Office of Water Research and Technology, U.S. Department of the Interior.

Comment (Donald Hey, Hydrocomp): I would like to discuss the Universal Soil Loss Equation. The EPA has done some extensive work on sediment runoff and sediment transport. The information is available. It examines sediment transport, event-by-event. This is based on research done at Stanford University about 10 years ago. It is based on kinetic energy of transport, rather than the empirical relationships. The person who is directing the research is George Bailey.

Comment: I would like to bring up one point on public acceptance. There are 12 states that have sediment control laws. Most of these states require the local jurisdictions to provide ordinances for control. Most of these laws do require stormwater management. They require storage--for example, from a 10-year, 24-hour storm to be released at a 2-year rate. Another point that I wish to make relates to the care that is needed in transposing information you get from a soil-loss equation to a construction site. For example, the soil loss equation is based on the top six feet of agricultural soil. Consider what happens when you go into a new construction site. You might excavate slopes 1½:1 to 2:1 with a depth of 30 feet. You have cut through the agricultural soil layer. You have a cut-slope of dense material with, perhaps, a bedding dipping into the slope. You take the material you cut and remold it by putting it into a fill. The cut-slope is not characteristic of the fill-slope. Also, any one portion of the cut-slope is not characteristic of another portion of the same slope. So, whatever you do be careful! But, even if you look at the soil-loss equation, you are saying that so much soil can escape. If you prevent that escape, why do you provide a soil-loss equation? Most of these approaches are based on a design concept, and most of the designs are based on the flow of water, not the sediment runoff. We, at EPA, have done a study on the effectiveness of erosion control structures. We found that you get 96% effectiveness. This is good, and it will get you an "A" everywhere. But, if you look at the fact that 10% of that 4% of material that escapes might be 100% of the fine-grained loam, the clays and the silts, have you really accomplished what you think you have? At the present time, we have another study going in which we are trying to find practical measures which can be used to control the fine-grained fraction. If we can get this accomplished, on a practical and economic basis, I think we can control all the sediment from a construction site. Again, you have to be careful! Every time you take an action, you have a reaction. When that runoff water escapes from a construction site, it has energy. It uses this energy to carry a sediment load.

If it has no load, it will erode the channel downstream. Then, you have an additional environmental problem.

Question (Douglas B. Cargo, Univ. of Texas at Dallas): I wonder if you would comment on the policy of the Soil Conservation Service as to stream or channel straightening and channelizing.

Bartee: Yes. Whatever action is needed in improving the channel, it would have to be a stable channel when the work is completed. There is a place for channel stabilization in handling stormwater. Straightening should be done only to the degree it is required to satisfy the need and the purpose so as to minimize the environmental effect.

SCS PRACTICES AS RELATED TO SEDIMENT AND EROSION CONTROL

by August J. Dornbusch, Jr.
State Conservation Engineer
Soil Conservation Service
U.S. Department of Agriculture
Athens, Georgia
(Presented with a slide presentation)

The Soil Conservation Service is a technical agency of the Department of Agriculture. We've been in existence since 1935. Our assistance is furnished to individuals who have soil, water, and erosion problems. Our technical assistance in these problem areas is backed up by research as well as the 40 years of experience. A good deal of the research has been done by the agricultural Research Service of the Department of Agriculture. Our technical assistance is provided through Soil and Water Conservation Districts. These districts are a unit of state government, and the services of the Soil Conservation Service are offered through these districts through a memorandum of understanding. From this arrangement, we provide assistance to the individual who has soil and water problems. He may be a landowner, farmer, or an individual in an urban area.

Conservation Plan

I'm sure that many times during this seminar you talked about "systems". Anytime we deal with stormwater, erosion, etc., we have to look at the"system".

Our approach to putting systems together for individuals is a plan called the soil and water conservation plan.

We develop this plan with the individual to fit his needs. It has to be a feasible plan, a workable plan, and technically sound.

Soils

Whatever we recommend to a landowner or provide assistance on, soils are the number one ingredient to be considered. We have to know the details about soils.

The Soil Conservation Service is responsible for mapping the soils over the United States. We put this into a manuscript or a Soil Survey Report. (For example, in Georgia we have 53 of the 159 counties covered and 19 more are in the publication process). We need and must have this kind of information all over the United States in order to know how to apply the best management practice that we talk about under Section 208.

For every acre of land, we need to know what type of soil it is. Each soil will have certain characteristics and certain capabilities and these can be related to what we call a soil series. The soil reports give interpretations of what a soil can do and how it will function. For example, if you were looking or studying an area to determine its suitability for septic tank operation, the Soil Survey Report can be used. The red colored portion of the map indicates severe condition, the yellow moderate, and green indicates slight problems. What this is saying is that in the red and yellow areas you must do something to these soils or manipulate them in some way to overcome the limitation so septic tanks could be installed. In addition, there are many other interpretations in the Soil Report, i.e., crop potential, irrigation requirements, suitability for road building and foundation for house building, recreation, woodland, and any number of interpretations that may be helpful in planning various type work.

If you're not familiar with these reports, contact your local Soil Conservation Service representative and he can help you.

Erosion

Now, I would like to talk about erosion. We are indebted to the

Agricultural Research Service for the development of the Universal Soil Loss Equation. It is a tool that helps us to estimate the soil loss which can occur for various soil types plus other parameters which are discussed below.

The equation is: A=RKLSCP where "A" is the computed soil lost per unit area, "R" is the rainfall factor, "K" is the erodibility factor, "L" is the slope length, "S" is the slope gradient factor, "C" is the crop management factor, and "P" is the erosion control practice factor.

Vegetation

In the development of a conservation plan, we look at a number of systems; and one of the things we consider is "vegetation". It is our number one defense against erosion. Hydroseeders are used along highways to vegetate steep road banks. Vegetation on strip-mine areas has been effective in reducing erosion. We have worked with school districts to get vegetation cover on their properties to keep erosion to a minmum. We also work with airports, such as we did here in Atlanta. Through a good vegetative plan, proper application and then proper maintenance, vegetation can greatly reduce the erosion problem.

Another important consideration in reducing erosion is our woodland vegetation. In Georgia, about 70 percent of the state is covered with woodland. Much of the forest floor is covered with a good layer of mulch which breaks up the impact of the raindrops and provides essentially a sponge to absorb some of the rainfall and thus reducing and slowing down the runoff. This combination reduces the amount of erosion that would otherwise occur.

Erosion Control Practices

Trees and grass are very important parts of a plan, but not all land areas can be so planted. We must have farmland to grow the food we all enjoy.

Every crop has varying ability to cover the soil during a growing season as well as provide a residue to cover the soil during fall and winter months. Often, the slope length of the land must be modified to get the allowable soil loss with tolerance for certain cropping systems. One method is to use contour strip cropping. This consists of alternate strips of close-growing crop (wheat) and row-crop (corn). This reduces erosion considerably. However, often contour-strip cropping is not enough to meet the minimum soil loss and thus making it necessary to break up the slopes with terraces.

In addition, with each of the systems discussed above, a water management system is needed. We prescribe primarily two types, (a) a grassed waterway with a stable outlet, or (b) a tile outlet system, or conduit, which uses a perforated inlet pipe and underground conduit to carry the runoff safely away. Animal wastes disposal is another problem on farms. Basically, the three practices that we deal with are: (1) the aerobic and anerobic lagoons, (2) the holding pond to catch runoff from feed lots, and (3) the holding tank where all the waste is caught. In each of these practices, the effluent must be placed back on the land and thus the need to be part of the conservation plan so adequate land can be available to spread the material. This, again, illustrates that it is necessary to look at the whole system.

We also provide assistance on many of the ponds we see on the country side. Ponds can be used in pastures to help distribute grazing by properly placing them as a drinking water source. This helps to reduce erosion by causing the animals to graze over large areas and thus reduce overgrazing of the vegetation. The ponds also serve for recreation and for wildlife habitats.

Irrigation is on the increase in the southeast. Mechanical irrigation systems are being used quite extensively for supplementing the lack of rainfall during the growing season. It is imperative that good erosion control and management systems be planned as part of the irrigation system to keep erosion within tolerable limits. Irrigation is another aspect that we want to think about in 208 planning since it is a method of applying waste effluent to the land.

Project Type Work

We also have "project" type operations. We have two types on which the SCS provides technical assistance. One is the Small Watersheds Program. The other is the Resources Development Program. We, basically, have several goals in the programs: (1) assist individuals within the watershed (hydrologic unit) to apply sound conservation measures; (2) floodplain management; (3) flood control, using structures; (4) recreation;(5) water supply; and (6) social-economics of the area.

I would like to talk about our work with counties and other governmental units in dealing with erosion control and sedimentation problems. A number of counties in Georgia tackled this problem of erosion and sediment control. Our assistance, basically, has been to aid the counties through the State Soil and Water Conservation District by reviewing plans that land developers submit. The State of Georgia enacted a sediment control act this past spring. The State Soil and Water Conservation Districts have been asked to take a leading part in review of these plans. Unfortunately, one of the things that is not in the Act is storm water management. When you look at the system, it is almost impossible to separate storm water management and sediment and erosion control.

There are many practices that we apply to farmlands that can also be applied in urban situations. You must envision scaling down the size of the project, and use imagination. If the slopes are too steep and you cannot solve the problems with vegetation alone, you may have to use mechanical means.

Site development plans need to provide methods of collecting sediment and keeping it on the site. In the same light, storm water runoff should be detained on the site and released at flow rates that will not cause problems on adjacent lands or downstream areas. If streams are overloaded with storm runoff, they may become unstable and result in erosion and deterioration of the stream. We need to make certain that we handle storm water properly.

Many states have developed manuals to aid individuals in the planning and designing of erosion and sediment control plans for areas undergoing urbanization and development. Georgia developed two of these manuals in 1972; one is standards and specifications and the other is a "how to do it" type manual. The State Soil and Water Conservation Committee is now revising these into one volume. They are also including storm water management as a section of this publication. It will also include a section on erosion control on mining area, as well as urban and development sites.

All people and all levels of government must pull together as a team to lick the non-point-source water pollution problems. Going our separate ways without coordination and direction would be a disaster and a waste of everyone's time.

The U.S. Soil Conservation Service has just released a document that deals with urban hydrology for small watersheds. If you want a copy, write to the state conservationist in your state.

COST EFFECTIVE APPROACH FOR COMBINED AND STORM SEWER CLEAN-UP

Dr. William C. Pisano*

This paper presents overview details of a study addressing the combined sewer problems in an old congested eastern community. The study emphasizes a multiplicity of principally non-structural micro controls in the upstream collection systems as well as several large downstream controls in contrast to an existing plan dominated by a massive downstream control program. The new plan cuts costs by more than 50%. In addition, some of the dramatic field inspection results raise questions concerning the adequacy of present combined sewer evaluations conducted in sec. 201, step 1 infiltration/inflow studies.

The general flavor of the approach may be interesting to 208 planning agencies desiring to stress non-structural Best Management Practices (BMP's) in combined sewer areas where prior 201 planning emphasized only structural solutions. The conceptual framework of this problem-solving strategy is also appropriate for designing 208 storm sewer planning efforts in both developed and developing areas. Although the methods used in this study represent a practical approach for addressing combined sewer problems, prototype studies in representative sample areas are recommended for 208 planning efforts because the level of detail and the associated costs are high.

Overview, Significance

Of all municipal-related pollution abatement problems, the most significant, in terms of cost and technical complexity, is storm and combined sewerage system overflow loadings. According to the U.S. EPA's latest survey, the costs of implementing controls on all municipal sources are estimated to be $350 billion. Of this total, nearly 75% or $261 billion would be required to control storm water runoff ($235 billion) and combined sewer overflows ($26 billion).

---

*Technical Director, Environmental Planning, Energy & Environmental Analysis, Inc. Boston, Massachusetts.

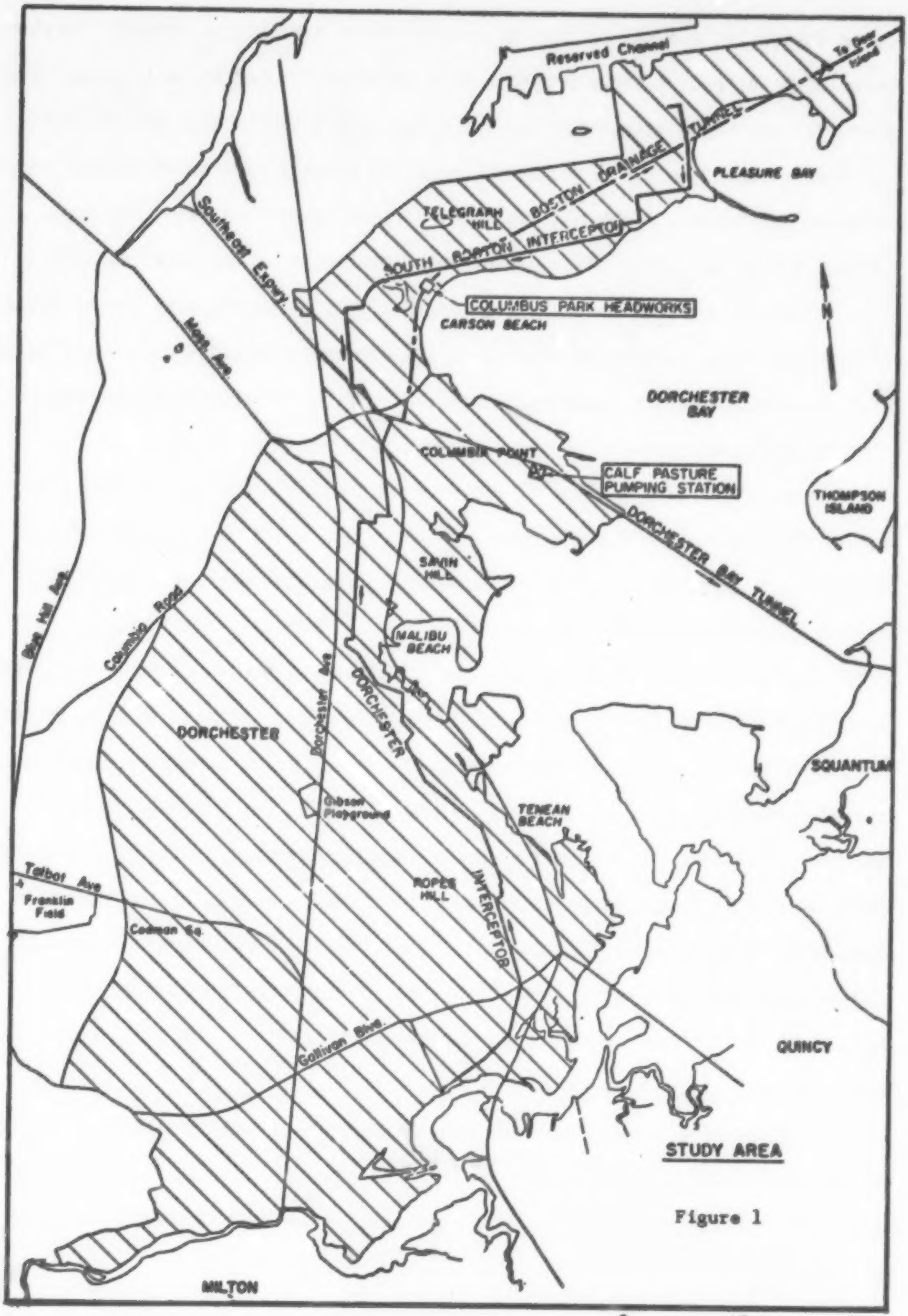
Quite obviously, amounts of this magnitude cannot feasibly be raised. Furthermore, costs of public works programs have never approached these figures. Even funds for highway construction have totalled only slightly over $75 billion.

Another questionable facet of the existing program is that structurally-oriented solutions for controlling combined sewer overflows generally imply periods of disruption in major urban areas, particularly the older eastern industrial cities, lasting years even decades. As such, the real social costs of applying these approaches will certainly exceed the present survey estimates that include only direct construction costs. The question then arises whether this is a viable tradeoff for the attendant water quality improvements.

The answer to this dilemma is not clear. The estimated monies will probably never be available and a more realistic view would be to spend limited dollars in maximizing the potential of existing capital outlays. The NPDES permit program recognized that the first and most logical step in fully utilizing our nation's municipal pollution control expenditures is to maximize existing treatment plant performance via non-structural options such as increase in O&M dollars, chemical additions, etc. Sewer system management can enhance the usefulness of existing combined sewerage systems, particularly for wet weather conditions. One aspect of sewer system management is a vigorous trouble-shooting maintenance program utilizing conventional means to cleanse troublesome deposition locations. Along these same lines, labor intensive municipal maintenance programs, heretofore considered unattractive, may become more viable in view of continuing high unemployment rates.

Detailed Case Study

The study area extends over the two high-density residential communities of Dorchester and South Boston in the metropolitan Boston area (see Figure 1). The topographical relief of the 3600 acre area is moderate to hilly and is


Reserved Channel
To Deer Island
BOSTON MAIN DRAINAGE TUNNEL
PLEASURE BAY
TELEGRAPH HILL
SOUTH BOSTON INTERCEPTOR
COLUMBUS PARK HEADWORKS
CARSON BEACH
Southeast Expwy.
Mass. Ave.
N
DORCHESTER BAY
COLUMBIA POINT
CALF PASTURE PUMPING STATION
THOMPSON ISLAND
DORCHESTER BAY TUNNEL
SAVIN HILL
MALIBU BEACH
Blue Hill Ave.
Columbia Road
DORCHESTER
Dorchester Ave
DORCHESTER INTERCEPTOR
SQUANTUM
TENEAN BEACH
Gibson Playground
ROPES HILL
Talbot Ave
Franklin Field
Codman Sq.
Gallivan Blvd.
QUINCY
MILTON
0
1/2
MILE

STUDY AREA

Figure 1

served mostly by combined sewers. The concern for pollution control in the area emphasizes reduction of fecal contamination to the five recreational beaches which border Dorchester Bay. The existing proposal for control of these overflows (combination of South Boston Pollution Control Program and Water Quality Improvement Plan for Tenean and Malibu Beaches) centered on collection and conveyance of combined and storm overflows at overflow outlets of the existing system, to a central pumping plant where the wastes were to be lifted and transported under pressure through highly congested areas to a terminal discharge location. The plan provided detention, chlorination and ultimate discharge of these wastes into Boston's Inner Harbor. Sewer separation and chlorination of several overflows not captured by the aforementioned system were additional components of the plan.

The estimated capital costs of the entire project exceeded $100 million and the time of construction was estimated at five to eight years. The degree of community disruption and the foregoing of beach recreational usage would have been great. The route of the proposed force main cuts through the highly congested residential streets of South Boston. The individual components of the plan, taken separately, offered only marginal improvements in water quality. The complete plan, however, would meet the 1974 water quality goals for Dorchester Bay.

The cost-effective approach described herein focused initially on maximizing the potential usefulness and flexibility of the existing sewer system for controlling combined sewer overflows and then considered capital-intensive components for further reduction of pollutant loads. The task of establishing a cost-effective control program divided into three categories: 1) understanding and identifying those remedial measures necessary to ensure maximum performance of the existing system; 2) quantifying the degree and effectiveness of upstream system management including sewer flushing and off-line system storage; and 3) determining the extent and magnitude of much larger downstream control measures such as large storage tanks to contain overflows, and chlorination facilities. Captured wastes were later released without chlorination to the sewer system.

A number of programs consisting of different mixes of the latter two categories of solutions were developed. Several extremely cost-effective remedial measures were found. The overall costs of these programs would range up to 40% of the existing proposal's capital costs.

The task of highlighting our control strategy can be best elucidated by summaries of the 6 major tasks accomplished in the study. Computational details of several new methodologies developed during the studies are not presented but will be available on request.

(1) MAPPING ACTIVITIES A comprehensive set of sewer maps depicting the hydraulic characteristics of interceptors, trunks and 37 collection systems was developed in order to understand the system. Piping networks of the 37 collection systems totaling 550,000 feet of sewers were then catalogued for hydraulic properties as well as computerized solids deposition predictions.

A novel graphical approach was developed to represent hydraulic profiles for each of the 37 combined sewer collection systems. Each collection system was drawn in profile view using roughly a manhole to manhole discretized representation. The segmented system included all combined, separate sanitary and storm sewers up to but not including house connections. Cumulative totals for each service type were given by a series of scales along the horizontal axis for each of the entry points to the collection system trunk sewer. These maps provided a quick visual informational basis for detailed field investigations, the computerized dry weather sewage deposition and flushing predictions, and the detailed assesment of the storage potential in collection systems.

(2) DRY WEATHER SEWER SOLIDS DEPOSITION PREDICTIONS. An empirical model based on shear stress considerations using literature data, was develnped to predict amounts of dry weather flow deposition in a single length of pipe. A multi-variate exten-

sion of this model was developed to predict amounts of daily deposition in any collection system network.

The model was used to predict the amounts of daily solids deposition in each segment of the Dorchester and South Boston collection systems. A total of 3,000 segments with average lengths of 180 feet was needed to represent these collection systems. Table I presents summary results for the 30 collection systems in Dorchester. Two important findings were that 10.3% of the total daily input solids will deposit, and that 50% of these accumulations occur in 100 sections of pipe, while 75% of these accumulations occur in 420 segments. Alternative sewer flushing programs were developed for these segments.

(3) SEWER FLUSHING PREDICTIONS. An empirical model was developed for predicting theoretical flushing volume requirements. Models were based on shear stress considerations and used literature experimental flushing results as a data base. The results are a series of simple single-term power functions that predict flushing volumes using only the pipe section hydraulic parameters. The computational procedures are outlined in Table II. These models were used to predict the amounts of water required per flush for each of the 420 sections of pipe determined in the daily dry weather flow deposition analysis. These calculations also provided a feasibility check on flushing since a number of segments had extremely flat grades.

(4) FIELD PROGRAMS. (Sewer System Diagnosis and Field Measurements)

a. Field inspections revealed that the commonly accepted view in Boston of the Dorchester Interceptor (see Figure I) being overloaded and needing replacement was erroneous:

i. A bricked-up side weir with ten missing bricks permitted seawater intrusion equal to half the interceptor's dry weather flow and about equal to 3% of the average flow at Deer Island, Boston's main treatment plant. Careful chloride, temperature and dye tracer surveys during high tide conditions uncovered this problem.

ii. The Dorchester Interceptor was found to be filled with fine granular and

TABLE I

ASSESSMENT OF MODERATE TO HEAVY DEPOSITION LOCATIONS, DORCHESTER COLLECTION SYSTEMS

BRANCH	TOTAL NUMBER COMPONENTS	AMOUNTS DEPOSITION (lb/day)	NUMBER COMPONENTS MODERATE TO HEAVY DAILY DEPOSITION	SUM OF DEPOSITION (lb/day)
Granite Avenue	392	695.3	69	438.4
Davenport Brook A	158	127.0	13	93.9
Davenport Brook B	58	23.3	7	13.4
Davenport Brook C	29	40.1	4	31.6
Rockne Street	19	4.8	2	2.1
Marsh Street	41	27.3	8	18.8
Hallet Street	12	21.6	8	21.4
Port Norfolk Street	52	92.0	29	86.7
Pierce Avenue	26	6.0	4	3.9
Coffey Street -	25	10.1	3	6.0
Neponset Avenue (S)	17	15.1	10	12.5
Neponset Avenue (N)	27	7.9	1	3.6
Freeport Street	4	0.4	-	-
Conley Street	20	26.3	16	25.1
Popes Hill Avenue	20	2.7	1	0.9
Commercial Point	30	22.4	13	17.5
St. Marks Road	200	70.9	39	35.0
Adams Street	43	10.7	2	2.1
Centre Street	290	407.7	61	195.8
Geneva Avenue	464	141.2	57	59.3
Kimball Street	51	22.0	9	13.9
Hancock Street	162	108.9	27	84.0
Deer Street	13	10.9	4	7.1
Dorchester Avenue	14	5.7	1	1.2
Bay Street	28	20.5	4	2.2
Saven Hill Avenue	21	7.3	2	2.1
Romsey Street	11	13.5	4	10.5
Elton Street	32	8.1	4	3.5
Hartland Street	28	25.3	7	20.8
Crescent Park	54	88.6	11	77.4
TOTAL	2361	1721.3*	420	1290.7

---

* Overall percentage of DWF suspended solids loadings depositing daily in Dorchester Combined Sewerage System equalled 10.3%

TABLE II

COMPUTATIONAL SUMMARY: FLUSHING MODEL

A) Experimental literature flushing data were used to relate flush wave height with flush volume and rate, and pertinent pipe hydraulic parameters.

B) Complicated open-form algorithms were developed to compute flush volume for circular and egg shaped pipes given shear stress requirements.

C) Simple closed-form predictive tools relating flush volume with pipe parameters were then developed using least squares curve fitting methods with little loss in precision.

Circle

$$V_F = \frac{13.5\,L^{1.45}\,D^{0.23}}{S^{1.4}}\,{}^{*} \qquad V_F = \frac{28.2\,L^{1.55}\,D^{0.09}}{S^{1.34}}\,{}^{**}$$

where

L = Length of pipe requiring flushing (100 ft.),

S = Pipe slope (ft/1000ft.),

D = Pipe dimensions (ft.), and

V_F= Flush volume (cf).

* Terminal Shear Stress = .04 PSF (Common value for separate domestic sewers)
** Terminal Shear Stress = .08 PSF (Common value for combined sewers)

Conditions Used to Develop Model (Step C)

A. Diameter:	8", 12", 18", 24", 30", and 36".
B. Length Flushed (ft.):	200, 250, 300, 350, 400, 450, 500 600, 700, 800, 900 and 1000.
C. Pipe Slope (ft./1000 ft.):	.5, 1, 1.5, 2, 2.5, 3, 4, and 5.

Note: Shear stress can be roughly related to minimum self-cleansing velocity.

organic sediments for nearly its entire length (13000 feet), resulting in the interceptor's capacity being cut roughly in half.

b. An inspection of all control structures and problem points in the system generated a remedial list of 23 items which during dry weather would eliminate approximately one million gallons of sewage daily from overflowing into Dorchester Bay.

c. Roughly 120 visual inspections of combined and separate sanitary sewer manholes were performed to corroborate theoretical deposition predictions. The agreement was remarkably good.

d. An automated wet weather sampling station was installed at the end of a combined collection system (25 acres) and operated to measure first flush phenomena and to verify deposition predictions for this system. A mass balance was performed during a wet event between the predicted solids accumulation and that flushed during a storm event. The closure was within 5%.

e. A number of heavily deposited sewers were flushed using different approaches for introducing the flush volumes. The experiments indicated that manual flush volume introduction by water tankers as an integral part of an active maintenance program at this point in time would be superior to any fully automated flushing systems. Reccommendation of automated flushing systems on a large scale must await long-term field studies to document their effectiveness and to develop operational procedures. The estimated costs of sewer flushing programs were based on automated equipment.

f. Water quality surveys of metropolitan beaches were performed following three storms of varying magnitude over a tidal cycle. The Coliform death rates were extremely high. These results were used to develop the death rate parameters for the water quality impact models.

g. The results of several marine in situ coliform death rate experiments performed under different conditions of sunlight showed that the time for 90% reduction occurs within 2 to 3 hours under sunlight conditions, while slight to zero rates were noted under conditions of darkness.

(5) ASSESSING STORAGE POTENTIAL.

a. The specialized collection system hydraulic profiles referred to earlier were used to locate potential storage sites "upstream" in the collection systems. The approach was to strategically locate small gravity-operated off-line storage tanks in uncongested areas such as parks, median strips, abandoned lots, etc. Their function was to capture and later release first flushes from heavily deposited upstream areas and also to detain potential overflows during small storms. Seventeen such structures were proposed.

b. Storage potential for much larger downstream sites was also assessed. These facilities would retain large overflow volumes for subsequent pumped discharge into the interceptor during the intervening dry periods.

(6) CONTROL AND ASSESSMENT

a. Overview: The analyses focused on water quality in terms of coliform concentrations. Earlier Boston Harbor studies indicated that control should emphasize reductions of coliform bacteria to enhance harbor water for water contact recreational use. It is fully realized that emissions of other pollutants such as organics, nutrients and heavy metals should also be reduced to minimal levels.

During the recreational period of May through November in the Boston area, a rainstorm of greater than .05" can be expected on the average of every four days. Thus, the objective was to find for a given control strategy and coliform standard, the average portion of time following a sequence of storms where the coliform levels fall below the standard. It is assumed that water contact activities during rainstorms would be negligible and therefore, the standards would not be applicable during this period. This approach supports water body assimilative capacity considerations.

Normally, facilities subject to random hydrologic fluctuations are designed to handle a storm of an assumed duration and frequency. When this procedure is applied to water quality management, it is tacitly assumed that a desired degree of water quality protection is equatable with a level of flood protection or urban drainage. Such an approach may lead to a misallocation of resources. The designs for effective hydraulic control of extreme hydrologic events may be substantially different from those for control of emissions from slight or moderate storms. The selection of a design storm for water quality analysis is difficult and poorly understood. It implies a knowledge of the benefits to the community that would ensue. In this study, a more direct approach to this dilemma was useful.

The idea is to subject the system discharging into Dorchester Bay to a series of hydrologic events of record, find the consequences (the overflows and their water quality impacts) for each event, and then summarize all results in terms of an average performance characteristic. The comparative advantages of the alternatives can be assessed in terms of the overall performance under a great variety of different conditions. This approach relieves the decision maker from the burden of connecting arbitrarily chosen frequency levels of storms with the corresponding system performance.

b. Models:

i. A computer model of the Dorchester, South Boston, and Neponset Valley sewerage system was developed that is roughly the equivalent of the HEC model, "STORM", This model routed, sequentially, through the sewer system model each individual rainfall event and antecedent dry weather period that had occurred at a local weather station during a 14-year period of record (677 events). The model then computed for each storm event, the amounts of BOD, suspended solids and coliform bacteria that were discharged to the Neponset River and to Dorchester Bay.

ii. An approach using the Boston Harbor Quality Model developed by Hydroscience, Inc. was used to compute for each storm event, the coliform bacterial pollution, dispersion and subsequent die off with time at each of the 5 beach areas in Dorchester Bay. Statistical analyses were then performed to assess the probabilities of satisfying various levels of water quality standards.

c. Alternatives Considered: The control alternatives as well as various combinations of these alternatives included:

Alternatives Developed by the Study

i. Removal of existing deposits from the Dorchester Interceptor;

ii. Elimination of seawater intrusion to the Dorchester Interceptor;

iii. Remedial measures to upgrade inoperative control structures and miscellaneous cleaning of plugged critical conduits;

iv. Daily flushing of critical sections of the present sewer collection system;

v. Installation of off-line storage facilities in Dorchester and South Boston;

vi. Chlorination at selected overflow points in the southerly portion of the Dorchester sewer system.

Alternatives from the "Existing Plan"

vii. Collecting, pumping and chlorinating combined sewage overflows from South Boston;

viii. Collecting, pumping and chlorinating combined sewage overflows from both Dorchester and South Boston.

d. Results: The effectiveness of different control programs in reducing BOD and suspended solids emissions from the Dorchester combined sewer system is shown in Figures 2 and 3, respectively. The loadings are presented in terms of tons discharged per recreational period (May-November). The removal of sediments which presently reduce the nominal interceptor capacity by roughly 50% is considered first. Next, three levels of sewer maintenance/flushing programs are considered along with various levels of off-line storage. Flushing programs A, B, and C denote, respectively: no action, low level program-100 sections (average length 180') and high-420 pipe segments. The low level flushing program (100 segments) represents an estimated 50% reduction of total daily predicted load (in 3000 segments).

Removal of sediments from roughly a 13,000 foot section of the Dorchester Interceptor is expected to reduce the BOD and suspended solids emissions to Dor-

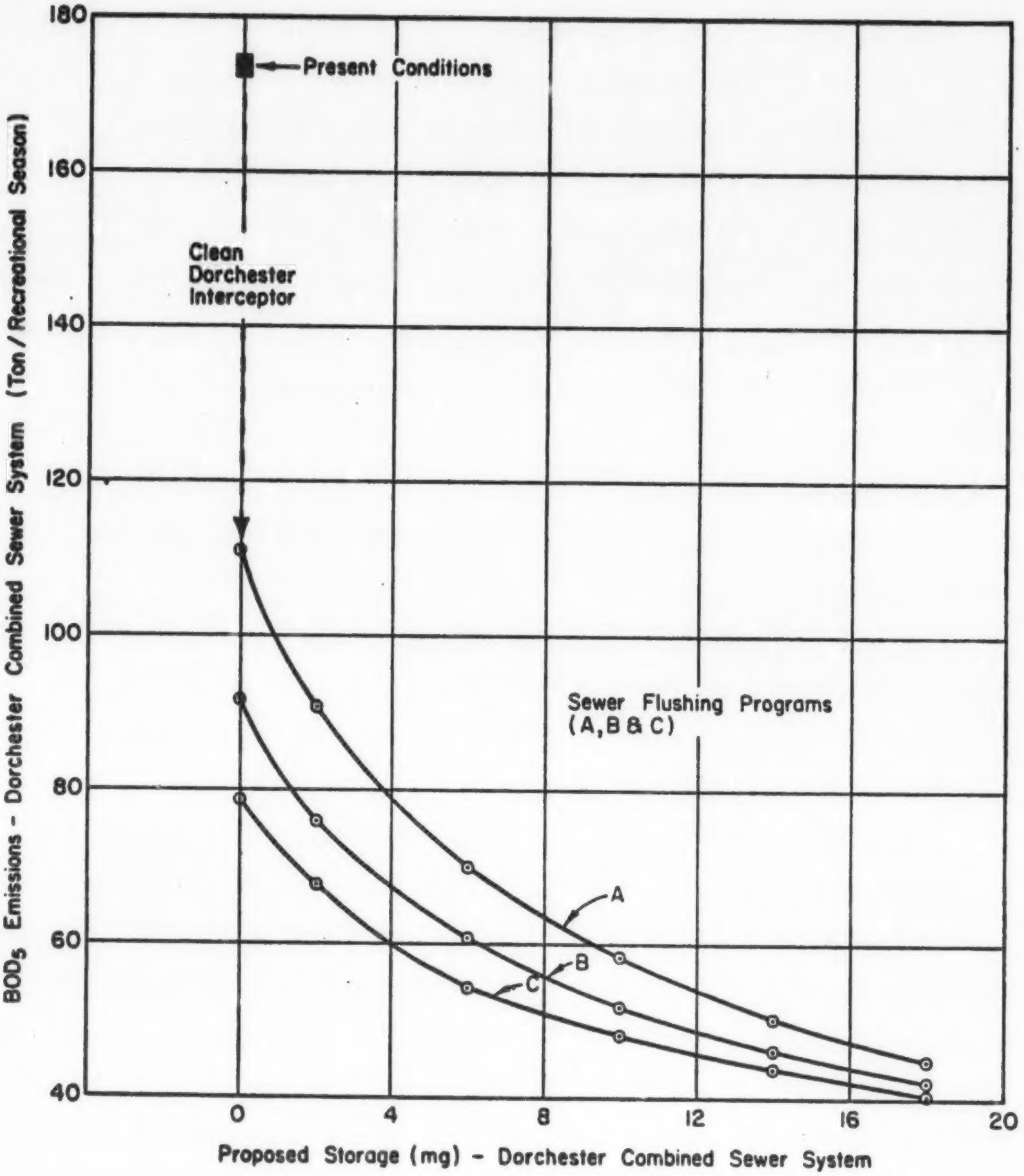


Figure 2 - Dorchester Combined Sewer BOD Emissions for Various Control Programs.

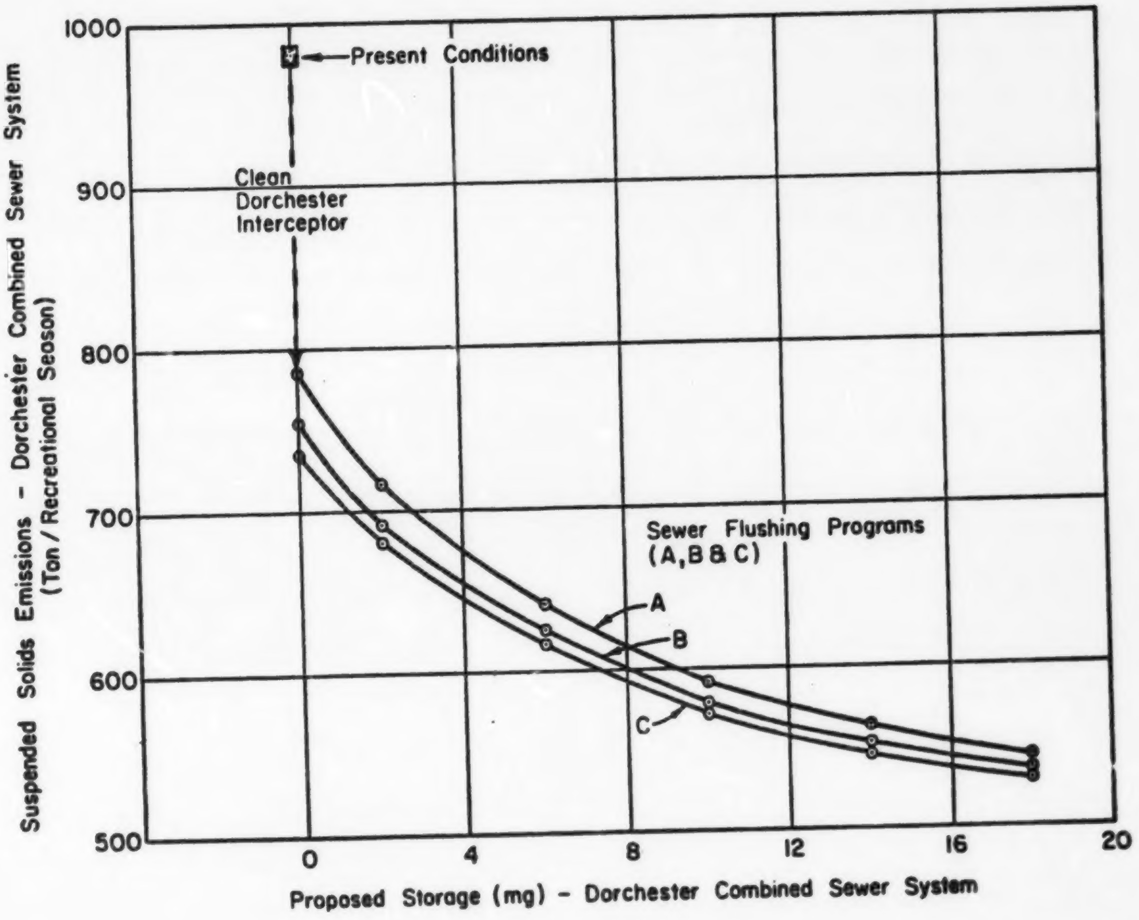


Figure 3 - Dorchester Combined Sewer Suspended Solids Emissions for Various Control Program.

chester Bay by 65 and 200 tons per recreational period, respectively. These pollutants will be treated at the Deer Island Treatment facility instead of discharging into Dorchester Bay. Sediment removal in the interceptor plus 2 MG storage in Dorchester will reduce the median overflow (present conditions) to negligible levels. This result underscores the fact that rainfall in Boston during the recreational period is characterized by high frequency, low intensity-small duration storms. Small amounts of storage completely capture or significantly clip the overflows from these events.

The coliform emissions during storm events were used as inputs into the water quality response models. Figure 4 presents a partial summary documenting the effectiveness of the various control programs. Response curves for the South Boston and Dorchester beaches are presented showing the percentage of the intervening dry periods between storms when the coliform levels were less than 1000 colonies/100 ml. Removal of sediment from the Dorchester Interceptor significantly improves the water quality at all beaches. Substantive water quality gains are realizable with the addition of only modest control programs. Cost estimates for each of the alternative programs associated with these curves and for mean coliform concentration response plots (not shown) permitted identification of overall least-cost programs.

The final results of the analysis are summarized in Table III. Program costs and the degree of water quality protection provided by each plan are shown. The first portion of the coliform standard limit constrains extreme event concentrations while the second, and much more difficult to attain, limits mean concentrations. Total present value costs include O&M over a 20 year period.

It can be seen from the table that Program I provides as much water quality protection as Program V. In addition, Program I provides (not shown) incrementally greater water quality improvement at the Dorchester Beaches than would Program V. The largest source of overflows is from the Dorchester system. Removal of the sediments in the interceptor simply reduces the magnitude of the problem.

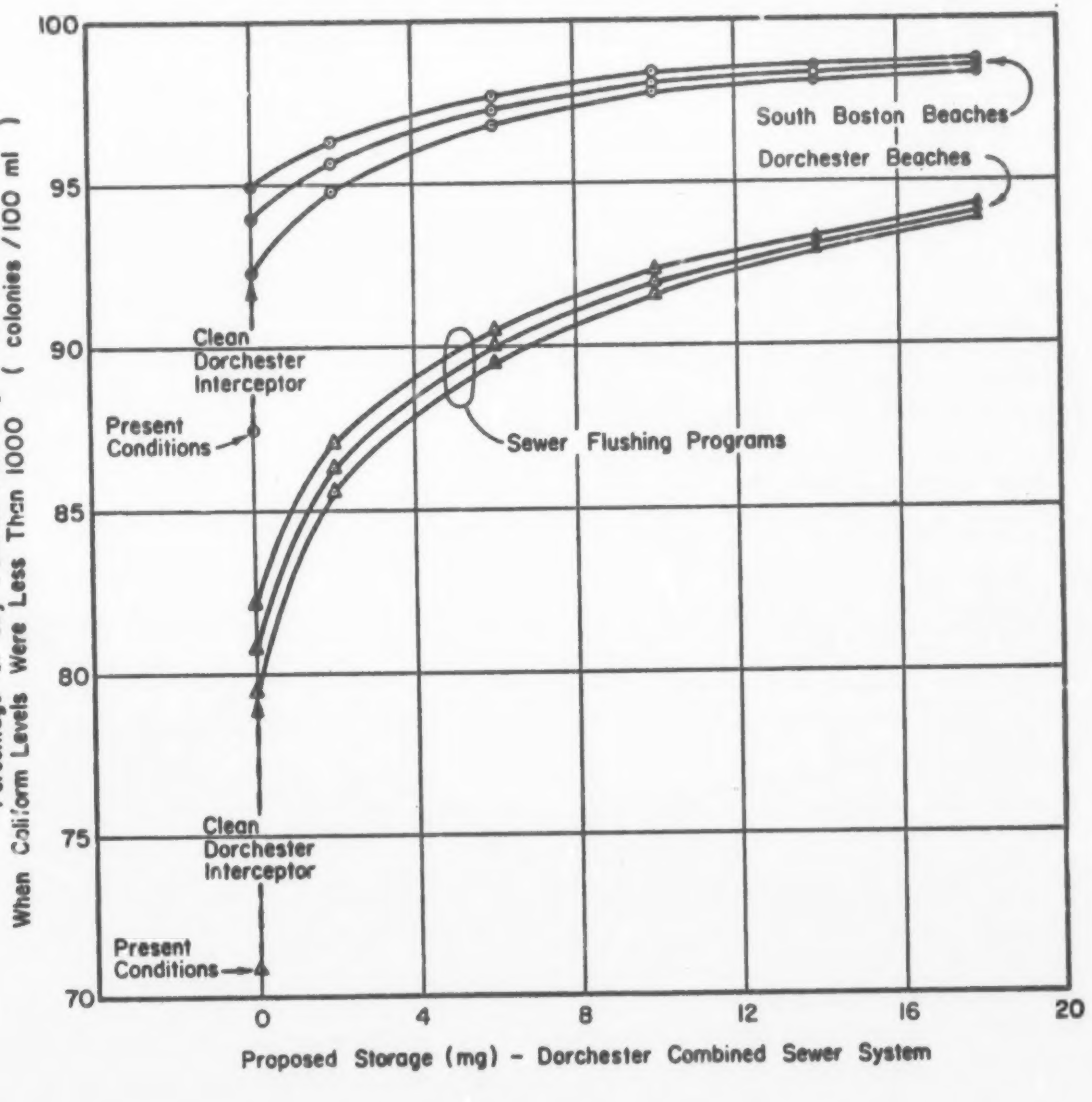


Figure 4 - Dorchester Bay Water Quality Response Characteristics for Various Control Programs.

TABLE III.PROGRAM SUMMARY

Acceptable Coliform Swimming Standards At:

PROGRAM	South Boston Beaches (3)		Dorchester Beaches (2)		Total Present Value Costs (millions)
	Extreme Std.	Mean Std.	Extreme Std.	Mean Std.	
NEW PROPOSAL					
I Basic Remedial Program, Sediment Removal in Dorchester Interceptor, elimination of seawater intrusion and small control program in South Boston.*	X	X			5
II Same as I plus 2 MG storage in Dorchester	X	X	X		8
III Same as I plus 11.1 MG storage in Dorchester plus Dorchester flushing program.**	X	X	X	1 of 2[†]	25
IV Program I plus: 18 MG storage in Dorchester, Dorchester flushing program** and chlorination of South Dorchester overflows.	X	X	X	X	38
EXISTING PROPOSAL					
V Old Harbor Plan (South Boston)	X	X			57***
VI Old Harbor Plan plus Malibu-Tenean Beaches Plan (South Boston and Dorchester)	X	X	X	X	100***

South Boston beaches: Pleasure Bay, L Street, and Carson Beach.
Dorchester beaches: Malibu and Tenean.

* South Boston Program consists of 1MG storage (4sites) plus flushing daily 22 critical sections.

** Dorchester flushing program: flushing daily 100 critical sections of pipe.

*** Capital costs only.

[†] Protection achieved at Malibu Beach.

Programs II and III are samples of intermediate programs and provide incremental water quality improvements for the Dorchester beaches. Program IV provides complete water quality protection for roughly 40% of the costs of Program VI. The control elements of Program IV derive from a cost-effective analysis wherein different combinations of storage, number of flushing sites and chlorination stations were considered, in order to meet the water quality standards. BOD and suspended solids reductions were also the greatest for the selected plan. The analysis showed that increased storage could be substituted for sewer flushing but would cost an additional $6 million.

CONCLUSION

There are several lessons to be gained from the case study. First, storm and combined sewer systems can and must be improved and managed just like treatment works. Computer oriented techniques coupled with thorough field and mapping activities permitted the identification of tailor-fit solutions. The results of this study cast doubt on whether the Federal requirements, promulgated as part of the facilities planning program (sec. 201), mandating consideration on a "one-time" basis correction of sewer system deficiencies via infiltration/inflow studies, are broad enough. Their general tenor emphasizes infiltration/inflow problems but neglects to assess remedial repair requirements to the sewer system, and gives only a cursory look at problems caused by deposits of solids during dry weather conditions. While the goal of obtaining watertight systems by reducing or eliminating infiltration/inflow is beneficial, its attainment in no way guarantees that the system is in good working order. These inadequacies largely stem from the fact that present studies are geared toward reduction of the hydraulic loadings to treatment plants, and are not necessarily keyed on ensuring proper sewer system performance during wet weather, overflow periods.

Second, many communities faced with combined and storm sewer problems must have the cost-benefit options developed and decide on the preferred approach. Rainfall-caused non-point source pollution stemming from storm and combined sewers cannot be solved by a uniform technological prescription without enormous cost and large scale community disruptions. Because the prices of some storm and combined sewer corrections are reasonable and others extraordinarily high, intelligent choices can be made only if the community benefits are weighed alongside the costs. Section 208 and Section 201 planning, directed by PL 92-500, requires that the alternatives be investigated before Federal funding is committed. The analytical approach demonstrated here permits this to be accomplished explicitly and early. Benefits, in this case total coliform counts and associated beach closings, are weighed against the cost of the control options. What price should we pay to swim during or after a one-in-ten-year rainfall event? What price should we pay to swim during normal rains? This approach permits a thorough exploration of such choices.

It should be clear that the building block approach presented herein has a direct analogue for both developed and developing separate storm sewer areas. In a conceptual sense, the first line of defense is obviously the imposition of land use restrictions and controls resulting in imperviousness changes. Next, erosion and sediment control practices can be imployed which can be constructed to last beyond the construction period. This level of control can be coupled with storm water management/flow attenuation concepts. The next step can be non-structural BMP's incorporating improved methods of street cleaning, anti-liter programs, storm sewer maintenance, i.e., catch basin cleaning, swirl regulator configurations, small retention basins, etc. Lastly, of course, more structurally oriented schemes of microstrainers, detention and chlorination can be used. The building block approach is logical and was shown to be cost-effective in the Dorchester combined sewer study.

In summary, the study clearly demonstrated that enormous advantages can be gained by a simple but thorough approach. Savings of many millions of dollars are anticipated because a good, hard (although admittedly difficult) look at the old existing system was performed. Such an approach, if utilized in other areas, can drastically reduce the national costs of combined and storm sewer cleanup. Maximization of the existing capital investments by utilizing the sewerage system to its fullest potential can result in tremendous cost savings.

ABSTRACT

This paper presents an overview of a recent study assessing the cost-effectiveness of a number of alternative plans for reducing the frequency and magnitude of combined sewer overflows from two large, densely populated communities in metropolitan Boston area. Controls included detailed field sewer inspections for both dry and wet weather conveyance adequacy, sewer flushing, upstream and downstream off-line storage and several chlorination facilities. Field inspections yielded extremely beneficial and cost-effective remedial measures. A generalized methodology was developed and utilized to predict sewer solids deposition in 0.5 million feet of collection systems covering 3000 acres. The approach was field verified. Daily flushing of 100 critical segments reduced total daily predicted solids deposition by 50%. Off-line storage alternatives were developed in collection systems as well as at major downstream overflow points. Coliform levels were monitored in marine waters during overflow periods for a tidal cycle. *In situ* coliform death experiments in marine environment were also performed. A runoff emission methodology was coupled with the Boston Harboe water quality simulation model to investigate over a 14 year historical period of record, the impacts of various combinations of control strategies in reducing fecal contamination. Cost-effective programs for various levels of water quality achievement were developed.

INDEX WORDS

Combined sewers, deposition, sewer flushing, sewer inspections, coliform death rates, emission/response modelling.

COLLECTION SYSTEM CONTROL

by

John A. Lager, Vice President
Metcalf & Eddy, Inc., Palo Alto, California

INTRODUCTION

As seen in the film, collection system control is one of the favored methods for reducing overflows and increasing the effective utilization of existing collection systems and treatment facilities. In this lecture, we will review the basic concepts, identify the components which make the system work, list some of the problems experienced in test applications, and view the approach from a cost-effectiveness evaluation.

Purpose

The purpose of collection system control is to utilize in-system storage, possibly augmented by off-line retention tanks, and flow routing to optimize the capture and treatment of wet weather flows.

Leiser [1] identifies the main objectives of the Seattle Metro system as:

1. To utilize the maximum storage capability of trunk and interceptor lines within a combined sewer system built to ultimate capacity so that overflows caused by storm inflow are reduced or eliminated.
2. To regulate daily flows to treatment plants, thereby aiding in the stabilization of the treatment processes and effectively increasing the dry-weather capacity of existing plants.
3. To select the overflow points which will cause the least harm to receiving waters, beaches and marine

life during intense storms when overflows cannot be avoided.

4. To eliminate the need for or reduce the cost of total separation of combined sewers which would be especially costly and disruptive to commercial and industrial areas of the city.
5. To monitor and control mechanical equipment within remote stations while accomplishing the above objectives and,
6. To retain dry- and wet-weather flow data of component collection systems for subsequent identification of infiltration problems and for potential charges in accordance with those flows.

Network Analysis

In order to make the system work, a series of integrated networks are required. Dispursed throughout these networks are data collecting points which transmit information continuously to a central processing unit. Here decisions are made whether to store, accelerate, or reroute flows and implemented through remotely operated gates, dams, and pumps. Success of the technique depends upon having excess storage and treatment available within the system and having sufficiently reliable instrumentation and controls to make point to point corrections during a storm.

THE CONTROL CONCEPT

The control concept developed from the knowledge that sewers, and in particular combined and storm sewers, seldom flow at their design hydraulic gradient which is selected on the basis of a maximum requirement. This maximum may be based upon the ultimate development of the area, the peak discharge expected from a rare, say one in five years, storm or a similar requirement. Thus, under normal flows only a small faction of a sewer's cross-sectional area is under water.

A simple example will illustrate what this volume may be in a combined sewer laid at a uniform gradient.

> Given conditions: area = 1,000 acres; population density - 30 persons per acre; design maximum rainfall - 2-in./hr.; runoff coefficient - 60 percent, ground slope 2.5 ft/1,000 ft. Computed peak dry and wet-weather flows: dwf = 30,000 x 100 gpcd x 2.5 pf = 7.5 mgd. wwf = 2.0 x 1,000 x .6 x .646 = 775.2 mgd. Conduit selection: c = 100; say 12 ft. dia at s = .0025; v full = 10.0 ft/sec; Q full = 775 mgd. Under dwf the conduit would be less than 5% full.

By constructing an inflatable dam to 0.6 the depth of the conduit, a storage impoundment of 0.76 million gallons is created prior to overflow (see Figure 1).

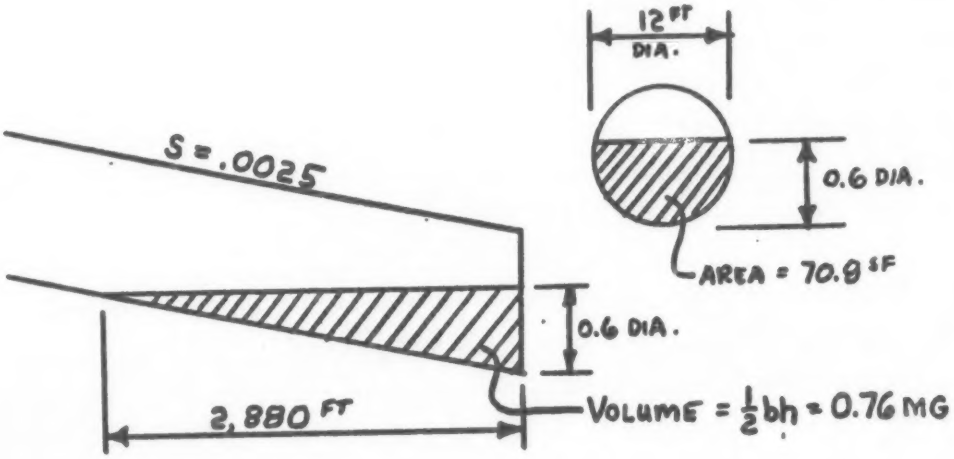


Figure 1. COMPUTED STORAGE VOLUME

This volume is roughly equivalent to the total runoff from a rainfall of 0.05-in over the entire area. Thus, it is seen that, except for unusual circumstances, the storage volume alone may not be significant unless backed up by a high rate of diversion to an available treatment facility. How high the treatment rate must be to be effective can be readily computed through simplified mathematical models as presented in the earlier lecture.

Components

The components of a remote monitoring and control system can be classified as either intelligence, central processing, or control [2].

The intelligence system is used to sense and report the minute-to-minute system status and raw data for predictions. Examples include flow levels, quantities, and (in some cases) characteristics at significant locations throughout the system; current treatment rates, pumping rates, and gate (regulator) positions; rainfall intensities; tide levels; and receiving water quality. Quality observations and comparisons may assist in determining where necessary overflows can be discharged with the least impact.

The central processing system is used to compile, record, and display the data. Also, on the basis of pre-recorded data and programming, the processor (computer) may convert, for example, flow levels and gate positions into estimates of volumes in storage, overflowing, and intercepted and may compute and display remaining available capacities to store, intercept, treat, or bypass additional flows.

The control system provides the means of manipulating the system to maximum advantage. The devices include remotely operated gates, valves, inflatable dams, regulators, and pumps. Reactions to actuated controls and changed conditions (i.e., increased rainfall, pump failure, and blocked gate), of course, are sensed by the intelligence system, thus re-initiating the cycle.

Operating Sequence

Before storm flow collection system control can be implemented, the direction, intensity, and duration of the storm should be known so that runoff quantities may be anticipated. Thus, the rain gage network forms an integral part of the system. Once the storm starts affecting the collection system, the flow quantity and movements must be known for decision-making, control implementation, and checking out the system response. The advantages of knowing whether or not an overflow is occurring are obvious, but consider the added advantage of knowing at the same time that the feeder line is only half full and/or that the interceptor/treatment works are operating at less than full capacity. By initiating controls, say closing a gate, the control supervisor can force the feeder line to store flows until its capacity is approached, or can increase diversion to the interceptor, or both. If he guesses wrong, the next system scan affords him the opportunity to revise his strategy accordingly.

Thus, system control or management converts the combined sewer system from an essentially static system to a dynamic system where the elements can be manipulated or operated as changing conditions dictate.

Degree of Automation

Because of the frequency and repetitiveness of the sensing and the short time span for decision-making, computers must form the basis of the control system. The complexity of the hydrology and hydraulics of combined systems also dictates the need for extensive pre-programming to determine cause-effect relationships accurately and to assist in evaluating alternative courses of action. To be most effective, real-time operational control must be a part of an overall management scheme included in what is sometimes called a "systems approach."

A block model of a complete automatic operational control system as developed by McPherson [3] is shown in Figure 2. This represents an ultimate system--hands off control-- and is a goal not yet achieved in major scale for management of water resource functions. The build up for such a system begins with remote real time monitoring. Next, the system is supplemented by certain remote control capabilities operated by a human processor at the control center. Finally, through the development of confirmed logic sequences, the controls are actuated directly by the computer with the supervisor providing only a safety override capability.

EXAMPLES

The degree of automatic control or computer intelligence level varies among the different cities. For example, in Cincinnati, monitoring to detect unusual or unnecessary overflows is applied and has been evaluated as being successful [4]. In Minneapolis-St. Paul, the Metropolitan Sewer Board is utilizing a central computer that receives telemetered data from rain gages, river level monitors, sewer flow and level sensors, and mechanical gate diversion points to assist a dispatcher in routing stormwater flows to make effective use of in-line sewer storage capacity [5]. The use of rain gages, level sensors, overflow detectors, and a central computer to control pump stations and selected

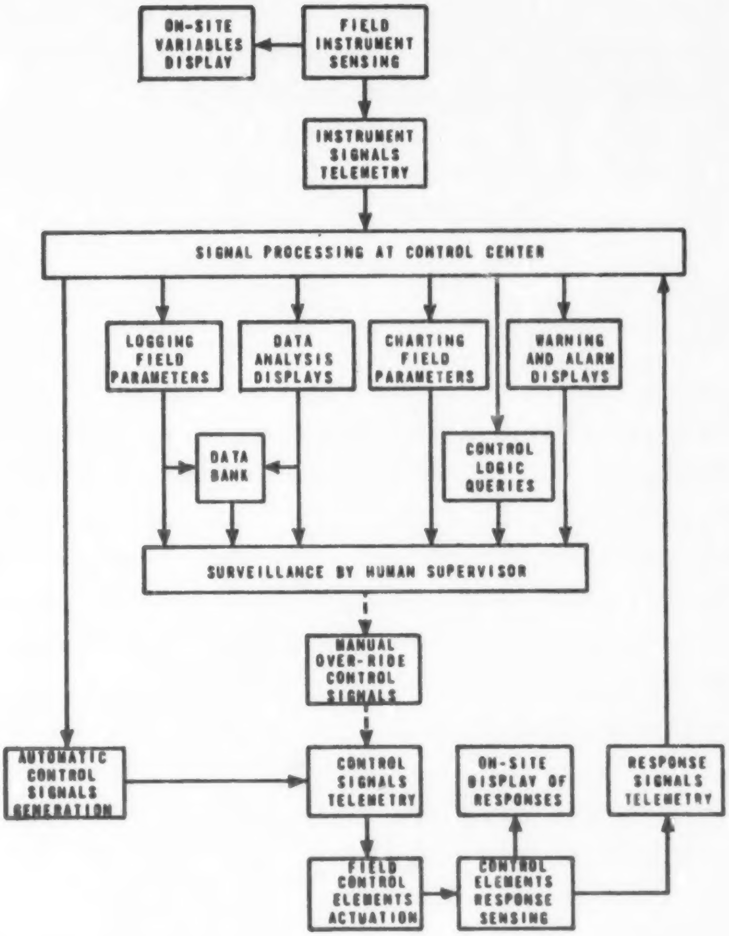

ON-SITE VARIABLES DISPLAY
FIELD INSTRUMENT SENSING
INSTRUMENT SIGNALS TELEMETRY
SIGNAL PROCESSING AT CONTROL CENTER
LOGGING FIELD PARAMETERS
DATA ANALYSIS DISPLAYS
CHARTING FIELD PARAMETERS
WARNING AND ALARM DISPLAYS
DATA BANK
CONTROL LOGIC QUERIES
SURVEILLANCE BY HUMAN SUPERVISOR
MANUAL OVER-RIDE CONTROL SIGNALS
AUTOMATIC CONTROL SIGNALS GENERATION
CONTROL SIGNALS TELEMETRY
ON-SITE DISPLAY OF RESPONSES
RESPONSE SIGNALS TELEMETRY
FIELD CONTROL ELEMENTS ACTUATION
CONTROL ELEMENTS RESPONSE SENSING

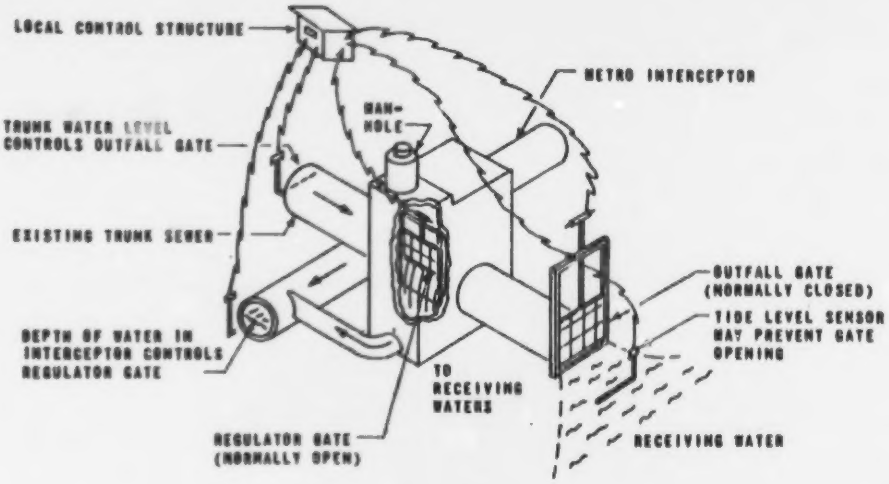
Figure 2. AUTOMATIC CONTROL SYSTEM

regulating gates is underway in Detroit [6] and Cleveland [7]. The City and County of San Francisco have embarked on a system control project for which the ultimate goal is complete hands-off computerized automatic control. They are currently collecting data on rainfall and combined sewer flows to aid in the formulation of a system control scheme. Typical regulator control devices are shown in Figure 3.

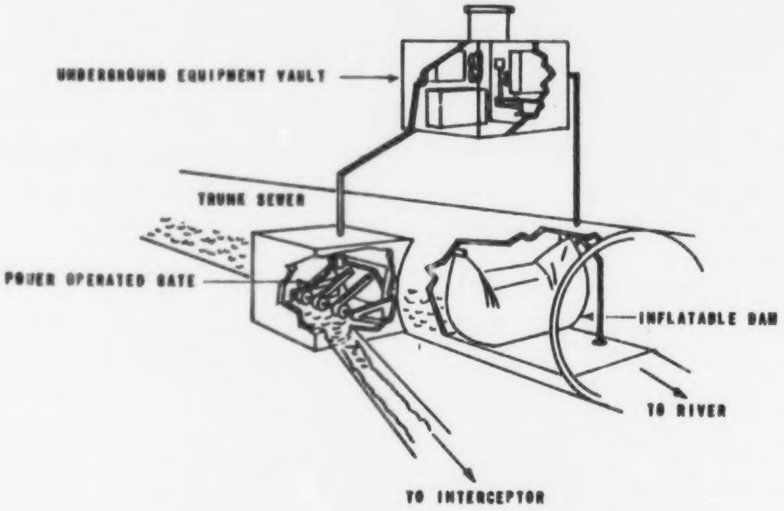
The cost-effectiveness of the system control approach and some of the problems are evident in the following specific example.

Seattle

The Municipality of Metropolitan Seattle (METRO) incorporates the main features of the above projects plus additional water quality monitoring and advanced control functions [8]. First operational in late 1971, the system presently has 15 fully equipped regulation stations and one major pumping station. All stations are monitored and capable of remote supervisory operation from a central control console. The estimated maximum safe storage in the trunk lines and interceptors, serving the 13,120-acre combined sewer area, is 32 mg, or roughly equivalent to 0.05 inches of runoff from the combined and partially separated areas. Interceptor capacity is generally 3 times the estimated year 2000 dry-weather flow. Through over three years of operation, the system has demonstrated the capability to reduce overflow volumes by 50 to 60 percent under supervisory control, and in excess of 90 percent under automatic program control during a period of unusually dry weather. Peak loadings to the receiving waters have been reduced by 80 to 90 percent and the occurrence of peak loadings has been shifted to higher rainfall rates which occur less frequently. The average loading reduction for


LOCAL CONTROL STRUCTURE
METRO INTERCEPTOR
MAN-
HOLE
TRUNK WATER LEVEL
CONTROLS OUTFALL GATE
EXISTING TRUNK SEWER
OUTFALL GATE
(NORMALLY CLOSED)
TIDE LEVEL SENSOR
MAY PREVENT GATE
OPENING
DEPTH OF WATER IN
INTERCEPTOR CONTROLS
REGULATOR GATE
TO
RECEIVING
WATERS
REGULATOR GATE
(NORMALLY OPEN)
RECEIVING WATER

(a) SEATTLE, WASHINGTON


UNDERGROUND EQUIPMENT VAULT
TRUNK SEWER
POWER OPERATED GATE
INFLATABLE DAM
TO RIVER
TO INTERCEPTOR

(b) MINNEAPOLIS-ST.PAUL, MINNESOTA

Figure 3. REGULATOR STATIONS
FOR IN-LINE STORAGE SYSTEMS

8 measured pollutant factors was 68 percent. The system is most effective in periods of light to moderate storms and performed poorly under a few intense summer storms.

During the course of program, the river water quality improved its dissolved oxygen content by 1 to 2 mg/L and the coliform counts in the river estuary fell by more than 50 percent.

The success of the computerized control management system is attributed to:

- surveillance and early attention to potential mechanical and control problems,
- early action and preparation for storm events,
- logical use of all available system storage to minimize combined sewer overflows.

The total capital cost for the system improvements was $5.3 million of which about half the cost was for the computer controls and station control equipment. This computes out to approximately $400 and $200 per acre respectively, which is about one to two orders of magnitude less than comparable master plan programs. Maintenance and operation costs average to $5 per acre per year.

Major problems included the protection of sensors from the hazardous environment, interfacing hardware, and the timing of the program which did not allow incorporation of the much advanced equipment technologies of the last few years.

CONCLUSIONS

Of all the abatement program options for large urban combined sewered areas, collection system control appears to be the easiest to implement and the shortest route to direct reduction of overflows to receiving waters. The available in-system storage will be widely variable between communities based largely on topography and characteristics of the interception network. Supplemental off-line storage will be required in most cases; however, the monitoring and control requirements will remain much the same.

As illustrated in the Seattle example, the initial level of improvement will be highly cost-effective, provided increased transport and treatment capacity is available.

REFERENCES

1. Leiser, C.P. Automated Collection System Instrumentation Needs. Proceedings of EPA Workshop on Research Needs for Automation of Wastewater Treatment Systems. Clemson University. September 1974.

2. Lager, J.A. and W.G. Smith. Urban Stormwater Management and Technology - An Assessment. Metcalf & Eddy, Inc. U.S. Environmental Protection Agency Report EPA 670/2-74-040. December 1974.

3. McPherson, M.B. Feasibility of the Metropolitan Water Intelligence System Concept (Integrated Automatic Operational Control). American Society of Civil Engineers. December 1971.

4. Caster, A.D. and W.J. Stein. Pollution from Combined Sewers, Cincinnati, Ohio. (Presented at ASCE National Water Resources Engineering Meeting. Memphis. January 26-30, 1970.) Preprint 1090.

5. Anderson, J.J. Real-Time Computer Control of Urban Runoff. ASCE J. Hyd. Div., 96, HY-1. 1970. pp 153-164.

6. Brown, J.W. and D.T. Suhre. Sewer Monitoring and Remote Control, Detroit. (Presented at ASCE Annual and Environmental Meeting. Chicago. October 13-17, 1969.) Preprint 1035.

7. Pew, K.A., R.L. Callery, A. Brandstetter, and J.J. Anderson. The Design and Operation of a Real Time Data Acquisition System and Combined Sewer Control in the City of Cleveland, Ohio. (Presented at the 45th Annual Conference of the Water Pollution Control Federation. Atlanta. October 1972.)

8. Leiser, C.P. Computer Management of a Combined Sewer System. Municipality of Metropolitan Seattle. U.S. Environmental Protection Agency. Report EPA-670/2-74-022. July 1974.

QUESTIONS AND ANSWERS

(Following John Lager's paper, "Collection System Control")

Question: In one of your slides, you indicated there was a increase of between 1 and 2 mg/l in dissolved oxygen. Is this increase attributable totally to the stormwater control system, and was this increase checked for cost-effectiveness?

Lager: That increase was adjusted to represent only that improvement due to the new control system that was in operation. It is based on more than one year of performance. To me, it represents a good indication of the cost-effectiveness of the system. But, you can't say that 2 mg/l divided into $5 million dollars comes to some broad dollar amount. Just how bad the stream is depressed to begin with is important. If it is 80% saturated and you improve it to 95%, it's remarkable.

QUESTIONS AND ANSWERS

(Following John Lager's paper "Collection System Control")

Question (Michael Seaman, Snohomish County, Washington): You showed us a very sophisticated system which seems to have a lot of potential, but I haven't seen much attention given by society or technologists to management of human wastes. In particular, I would like to hear your comments on such things as: reclamation; reuse of water; conservation incentives to discourage consumption of water, thereby reducing loadings on sewage treatment plants; decentralized systems such as units installed in buildings to recycle water in homes or office buildings; and integration of energy recovery systems.

Lager: The first part of your question, relating to correction of urban problems, should involve entrapment of the water at the earliest opportunity. You can see this in any study, nationwide. The major motivation of any analysis should be the earliest possible capture of the stormwater in impoundments such as in grassed areas of cloverleaf highway intersections and in impoundments located in extreme upstream sections of the system. Rainwater is the primary source of drinking water. If we could catch it up in the air before it passes through air pollutants, we would have the purest water obtainable. Also, when it first hits the land, rain water is continually picking up pollutants all along its path. As it progresses farther downstream in the system, correction measures become more costly and land is more expensive. All of these factors provide a great incentive to trap it as early as possible. I think that this bears directly on your question concerning reclamation. The earlier you trap the stormwater--the better the quality, the more water you can infiltrate into the groundwater strata and the less cost involved in making the water reusable for various purposes. I see little merit in individual home systems because of the attendant operational supervision problems. Concerning your question on energy recovery, I don't see major energy potentials in handling stormwater other than for hydroelectric generation. This was given consideration as one of the components of the Chicago Tunnel and Reservoir Plan. (Editor's note: This aspect of the plan has not been incorporated into the project design). We are dealing with intermittent and unpredictable circumstances. We know that, on long term, we will get so many inches of rainfall in a year on an average; but we can never count on a specific happening at a specific time.

Question (Cecil Ouellette, Oregon Operations Office, EPA): At Seattle Metro, how did they gain public acceptance for the collection control system for their sewer network? Secondly, what was the source of funding and the breakdown of the $ 5.3 million total cost?

Lager: I think that both of those questions will be covered by one of our speakers tomorrow. He will discuss the implementation and financing of such programs. I feel that the Seattle Metro project had the widest public acceptance of any in all the areas that I visit in analyzing stormwater programs.

Comment (Rod Stroope, Seattle Metro): I can't tell you what the cost breakdown was. As far as public acceptance is concerned, it is an in-system modification. It involves changes to the collection and treatment systems. So, there isn't really a great deal of public involvement other than for those public facilities that are to be located above the ground. One such facility produced public concern and, as a result of required environmental impact statements, extraordinary controls were placed on the construction of the facility. I urge 208 agencies that do not have operational responsibility to develop contact with the operational agency in your respective areas, especially where there are specific combined sewer problems or aspects to the plan being developed. The operating agencies face, on a day-to-day basis, extremely variable flows in the combined sewer system every time it rains. Conservation methods and deduction of dry-weather sewage flows is a long-term thing that 208 agencies need to address from a policy standpoint. In the meantime, before we can reduce the flows significantly, the operators have to do something with these flows. This is the type system we chose. It does appear to be effective for that first light rainstorm.

Lager: I would like to add a comment on public acceptance. In contrast to the Seattle area, let's look at the San Francisco project where, because of the steep topography, they don't have any in-system storage capability. The alternative that they identified is to construct off-line, upstream detention basins. This met a great deal of public resentment because it involves long periods, perhaps six months, when major street intersections in residential areas will be torn up while they build these concrete stormwater vaults below street level. After installation, everything will return to normal, but it is that disruptive period which carries the same stigma as sewer separation construction procedures.

A COST-EFFECTIVE SWIRL COMBINED SEWER OVERFLOW REGULATOR/SOLIDS-SEPARATOR

Richard I. Field
Chief, Storm & Combined Sewer Section
(Edison, New Jersey)
Municipal Environmental Research Laboratory
U. S. Environmental Protection Agency
Cincinnati, Ohio 45268

Although this paper is on the swirl as applied to a combined sewer area, it offers direct application for separately sewered and unsewered flow control.

An intensive study to develop a new type of combined sewer overflow regulator device, called swirl, was conducted under the general supervision of the U. S. Environmental Protection Agency's (EPA) Storm and Combined Sewer Technology Program (Edison, New Jersey), Municipal Environmental Research Laboratory, Cincinnati, Ohio. The background, design, and operation of this device has been described previously;[1-5] however, these areas were based on hydraulic and mathematical modeling to optimize swirl regulator/separator configuration and determine its design basis. An overhead view of the hydraulic model in operation is shown in Fig. 1. The object of this paper is to describe the results of a full-scale prototype swirl unit that controlled real overflows in the City of Syracuse, New York. This project is jointly sponsored by EPA and Onondaga County, New York, under ongoing EPA Demonstration Grant No. S-802400.

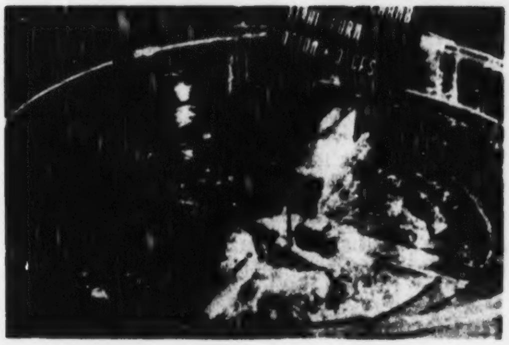


Fig. 1. Overhead View of Swirl Regulator/Separator In Operation, Laboratory Hydraulic Model, LaSalle, Quebec, Canada

COMBINED SEWER PROBLEMS

Untreated overflows from combined sewers are a substantial water pollution source during both wet- and dry-weather periods. There are roughly 15,000 to 18 000 combined sewer overflow points in the USA.[6] It has been estimated that on a national level the expenditure for combined sewer overflow pollution abatement would be $30 billion.

In considering wet- and dry-weather water pollution abatement, attention must first be directed to control of the existing combined sewerage system and replacement or stricter maintenance of faulty regulators. Consulting and municipal engineers will agree with findings[1,2,6,7] that regulator mechanical failures and blockages persist at the overflow or diversion points resulting in unnecessary by-passing, a problem also occuring during dry weather. Malfunctioning overflow structures, both of the static and dynamic varieties, are major contributors to the overall water pollution problem.

The practice of designing regulators exclusively for flowrate control or diversion of combined wastewaters to the treatment plant and overflow regulator facilities for improving overflow quality by concentrating wastewater solids to the sanitary interceptor and diverting excess storm flow to the outfall will pay significant dividends.[1,2,3,7] A new phrase has been coined, the "two Q's," to represent both the quantitative and qualitative aspects of overflow regulation.[1,3] "Regulators and their appurtenant facilities should be recognized as devices which have the responsibility of controlling both quantity and quality of overflow to receiving waters, in the interest of more effective pollution control."[3]

GENERAL DESCRIPTION

The swirl flow regulator/separator is of simple annular-shaped construction and requires no moving parts. An isometric view of the device is shown in Fig. 2. It provides a dual function--regulating flow by a central circular weir-spillway while simultaneously treating combined wastewater by swirl action, which imparts liquid-solids separation. Dry-weather flows (dwf) are diverted through a cunette-like channel in the floor of the chamber into a bottom orifice located near the central standpipe discharging to the intercepting sewer for subsequent treatment at the municipal plant. During higher flow storm conditions, the low-volume concentrate is diverted via the same orifice leading to the interceptor, and the excess, relatively clear, high-volume supernatant overflows the center circular weir into a downshaft for storage, treatment, or discharge to the receiving stream. This device is capable of functioning efficiently over a wide range of combined sewer overflow rates and has the ability to separate settleable light-weight organic matter and floatable solids at a small fraction of the detention time required for primary separation--seconds to minutes as opposed to hours.

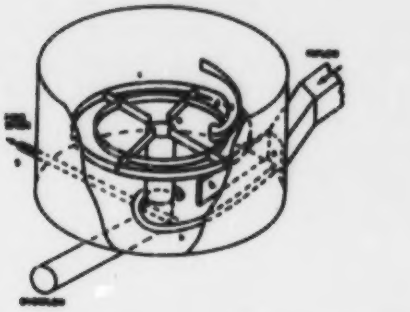


Fig. 2. Isometric View of Swirl Regulator/Separator. Legend: a. Inlet Ramp; b. Flow Deflector; c. Scum Ring; d. Overflow Weir and Weir Plate; e. Spoilers; f. Floatables Trap; g. Foul Sewer Outlet; h. Floor Gutter

SYRACUSE PROTOTYPE

A 3.6 m (12 ft) diameter swirl combined sewer overflow regulator was installed at West Newell Street in Syracuse, New York. The overflow is from a 54-acre, single-family residential tributary area. Since on-site inspections confirmed full-pipe flow conditions occurred during normal springtime overflows, design flow to the swirl was based on maximum carrying capacity of the 0.6 m (2 ft) inlet combined sewer or 23.4 cu m/min (8.9 mgd). A profile of the West Newell Street swirl prototype is shown in Fig. 3.

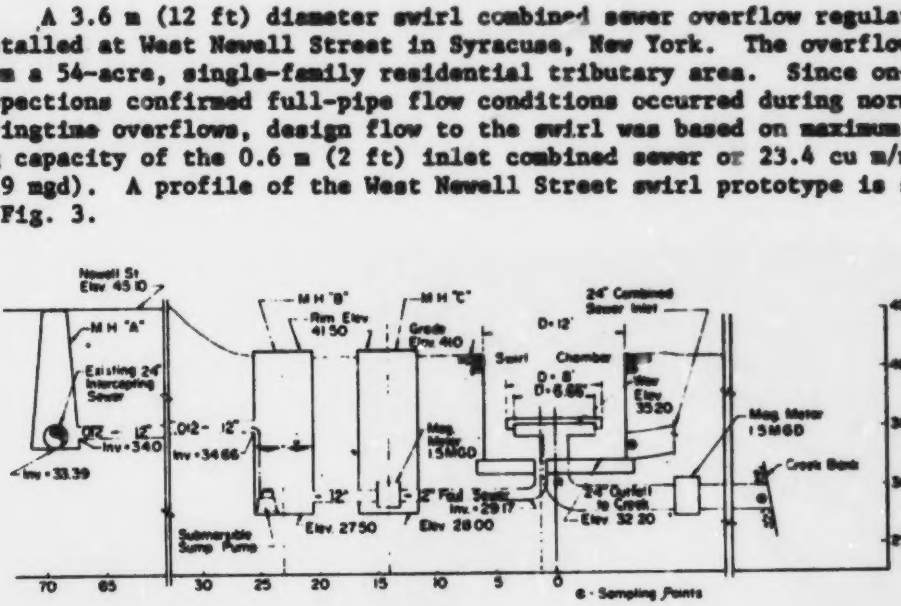

Newell St
Elev 45.10
M H "A"
Existing 24" Intercepting Sewer
.012 - 12"
Inv • 34.0
Inv • 33.39
M H "B"
Rim Elev 41.50
.012 - 12"
Inv • 34.66
12"
Submersible Sump Pump
Elev. 27.50
M H "C"
Grade Elev 41.0
Mag. Meter 1.5 MGD
2" Foul Sewer
Inv. • 29.17
Elev 28.00
24" Combined Sewer Inlet
D • 12'
Swirl Chamber
D • 8'
D • 6.86'
Weir Elev 35.20
24" Outfall to Creek
Elev 32.20
Mag. Meter 15 MGD
Creek Bank
45
40
35
30
25
70
65
30
25
20
15
10
5
0
● - Sampling Points

Fig. 3. Profile of Swirl Regulator, West Newell Street, Syracuse New York

HYDRAULIC LIMITATIONS OF SITE

To avoid pumping, it is best that the swirl regulator fit between the hydraulic gradients of the combined sewer inlet and the interceptor receiving the foul outlet flow; however, this desirable condition did not exist at West Newell Street. Owing to the limited hydraulic head between sewers, dry-weather flow (by gravity) would have resulted in a standing depth of 0.9 m (3 ft) in the swirl chamber. This would have caused solids accumulation and possible anaerobisis in the interim periods between storms. Thus, a submersible pump was installed downstream of the foul sewer outlet line which operated during dry weather.

OVERFLOW OPERATION

The facility was designed for immediate response to an overflow condition. An ultrasonic flowmeter on the 0.3 m (12 in) foul sewer outlet line measures dwf and the foul concentrate to the interceptor during wet-weather flow. The average dwf range is approximately 1.3 to 2.0 cu m/min (0.50 to 0.75 mgd). Since the downstream capacity of the interceptor is 3.4 cu m/min (1.3 mgd), the flowmeter signal deactivates the submersible pump when 3.4 cu m/min (1.3 mgd) flow is reached. Flow in excess of 3.4 cu m/min (1.3 mgd) will be forced over the central overflow weir, measured by an electromagnetic flowmeter, disinfected, and discharged to the receiving stream.

When the overflow subsides, the flowmeter in the outfall pipe signals the flowmeter in the foul outlet line, which reactivates the pump and lowers the water level in the swirl chamber to allow free gravity flow in the floor gutter to prevent solids from settling until the next overflow. Figs. 4 and 5 illustrate the dry- and wet-weather swirl operation, respectively.

Fig. 4. Swirl Regulator--Wet Weather Operation. West Newell Street, Syracuse, New York

Fig. 5. Swirl Regulator--Dry-Weather Operation, West Newell Street, Syracuse, New York

Sampling is performed at the inlet and outfall locations (depicted in Fig. 3) at fifteen-minute intervals (later changed to five-minute intervals) during overflow events. The samples were analyzed for suspended solids (SS), settleable solids, 5-day biochemical oxygen demand (BOD_5), total organic carbon, heavy metals (copper and zinc) and fecal coliform. Suspended solids and BOD_5 are addressed on this paper.

COARSE FLOATABLES REMOVAL

The coarse floatables/scum removal mechanism has worked satisfactorily. Visual observations during overflow events revealed floatables to be effectively contained by the scum ring in the outer ring of the chamber, and forced into the floatables trap (under the weir plate) by the swirl action for subsequent draw-down and removal to the foul sewer during dry weather. Fig. 6 illustrates floatables entrapment during wet-weather operation.

On occasion some floatables have been trapped between the scum ring and the overflow weir as the water level in the chamber rises from its dwf to overflow condition. In general such floatables have been lost to the treated overflow.

MAINTENANCE

Initially, a double-vaned impeller type submersible pump was installed but was subject to clogging problems due to coarse objects, e.g., bottles, cans, rags, and bricks. This was rectified by the installation of a single-vaned pump which reduced maintenance frequency from an average of once a week

Fig. 6. Swirl Regulator--Floatables Entrapment During Wet-Weather Operation, West Newell Street, Syracuse, New York

to once a month. Because of solids buildup, the longer the low dwf period between the storms, the more frequent the maintenance required. Periodic pump clogging also occurs from the accumulation of debris during overflow when the pump is not operating.

Manual hosing of the chamber walls and floor was necessary after each overflow event. As an overflow subsided, the flow-through time in the swirl increased from 23 sec (at maximum flow) to 9 min (at minimum flow) resulting in shoaling of solids on the chamber floor. Subsequent dry-weather flow velocities were not great enough to carry accumulated solids to the floor gutter and through the foul sewer outlet. Automatic washdown facilities would eliminate the need for manual hosedown resulting in reduced maintenance. The frequency of swirl chamber cleaning is approximately once per month.

Estimated manpower requirements for the swirl at West Newell Street are 48 hrs/yr (4 hrs/clogging x 12 clogs/yr) for submersible (single-vaned impeller) pump cleaning, and 40 hrs/yr (4 hrs/overflow x 10 overflows/yr) for chamber cleaning, totaling 88 person-hrs/yr. Cost-wise, maintenance amounts to $1,800/yr.

SOLIDS SEPARATION EFFICIENCIES

Hydraulic Model --

Based on laboratory hydraulic model studies,[3,4,8] SS removal efficiency for the swirl should be approximately 65 percent. Particle removal effectiveness was determined to be a function of its effective diameter and specific gravity (or settling velocity). For grit with specific gravity of 2.65 greater than 0.3 mm (0.012 in), removals were greater than 90 percent which decreased to less than 40 percent for 0.1 mm (0.004 in) grit. For settleable solids with specific gravity of 1.20 and larger than 1.0 mm (0.04 in), efficiency ranged from 80 to 100 percent; and for 0.5 mm (0.02 in), particle removal efficiencies decreased to about 30 percent and less than 20 percent for 0.3 mm (0.012 in) particles. An accurate comparison of prototype vs model removal efficiencies cannot be made until settling column tests are performed for the West Newell Street prototype flow.

Prototype --

Relatively good SS removal efficiencies were determined over the entire storm-flow range for this prototype (Table 1). Total mass loading and concentration removal efficiencies ranged from 44 to 65 percent and 18 to 55 percent, respectively, as flowrates ranged from relatively minor flows of 0.54 cu m/min (0.2 mgd) to a high of 13.2 cu m/min (5.0 mgd). Figs. 7 and 8 illustrate the total SS mass removals with respect to time and storm flowrate. The shaded areas between curves indicate a trend of higher removals at storm onset when concentrations are generally higher and again near the end of the storm when flowrates drop.

Table 1. Suspended Solids Removal

	Swirl Concentrator						Conventional Regulator		
	Mass Loading kg			Average SS per storm, mg/l			Mass Loading kg		
Storm No.	Inf.	Eff.	% Rem.[b]	Inf.	Eff.	% Rem.[b]	Inf.	Underflow	% Rem.[a]
02-1974	355	167	53	535	345	36	355	143	40
03-1974	321	179	44	182	141	23	321	96	30
07-1974	50	18	65	110	90	18	71	15	21
10-1974	394	215	46	230	164	29	394	94	24
14-1974	108	61	43	159	123	23	114	41	36
01-1975	127	48	62	374	167	55	230	127	55
02-1975	432	190	56	342	202	41	432	149	35
06-1975	117	64	45	342	259	24	117	42	36

[a] For the conventional regulator removal calculation, it is assumed that the SS concentration of the foul underflow equals the SS concentration of the inflow.

[b] Data reflecting negative SS removals at tail end of storms not included.

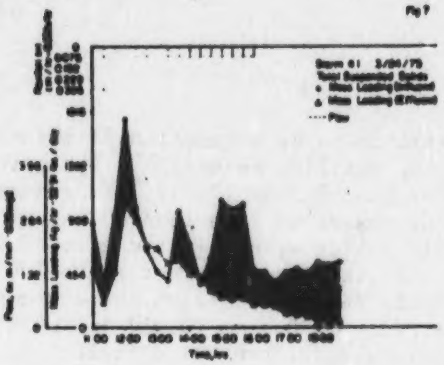


Fig. 7. Swirl Regulator Suspended Solids Removal, West Newell Street, Syracuse, New York

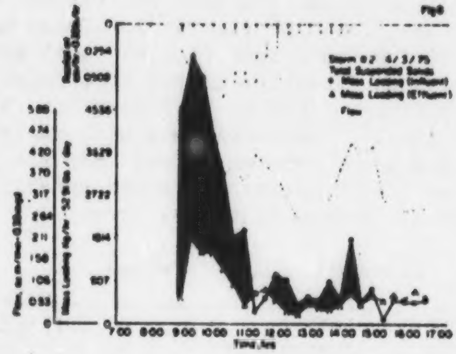


Fig. 8. Swirl Regulator Suspended Solids Removal, West Newell Street, Syracuse, New York

Fig. 9 further reveals the trend of greater SS mass loading reduction as the SS influent concentrations increase. Suspended solids influent concentrations greater than 250 mg/l generally resulted in removals of better than 50 percent of the total mass loading to the swirl.

Care must be taken in evaluating swirl solids treatability since under dwf conditions all regulators are designed to divert the entire flow volume and associated solids to the intercepting sewer until a predetermined overflow rate is reached. This diversion continues throughout the storm. The swirl has the added advantage of concentrating solids as well as conventionally bypassing flow during overflow events. This concentrating effect is evidenced by removal efficiencies in terms of SS concentrations varying from 18 to 55 percent (Table 1), as previously stated.

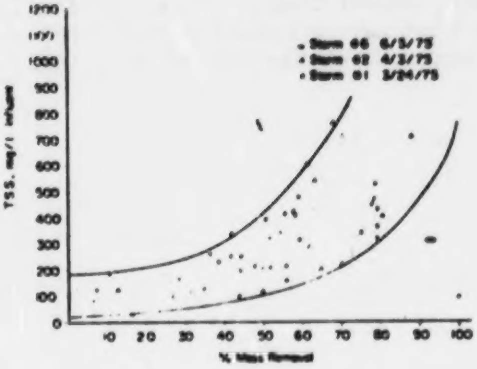


Fig. 9. Swirl Regulator Suspended Solids Influent Concentration vs Percent Mass Loading Removal, West Newell Street, Syracuse, New York

If a hypothetical swirl regulator was developed that did not concentrate (as is the case for conventional flow regulators), the net mass loading reductions (attributable to the SS conventionally going to intercepted underflow) would have ranged from 21 to 55 percent (Table 1). This may be a better way to compare the effectiveness of the swirl to conventional combined sewer overflow regulators.

For low-flow storms, approaching the maximum dry-weather capacity of the interceptor, the advantages of swirl concentration are reduced as would be expected based on the physical principal involved. In other words, as the ratios of inflow to foul outlet underflow or weir overflow to foul outlet underflow decrease, the SS removal advantage from swirl concentrating also decreases, since the intercepted hydraulic loading to underflow becomes more significant in the net mass loading calculation of the hypothetical conventional regulator. This phenomenon is exemplified by the SS total compared to SS net mass loading removals of Storm No. 1-1975 (which was of relatively low intensity compared to the other storms) (Table 1), where the hydraulic loadings to the swirl were low, approaching dry-weather conditions.

Many outfalls are designed to pass 20, 100, and even 1,000 times average dwf as opposed to West Newell Street which, at best, passes only 10 times average dwf. For these cases, the swirl concentrating effect will exhibit greater advantages than found with the Syracuse prototype over conventional regulators for SS mass removal.

BIOCHEMICAL OXYGEN DEMAND

Since non-biodegradable synthesized solids were used, no evaluation of BOD_5 removal was made in the laboratory swirl hydraulic model. Prototype analyses indicated greater than 50 percent BOD_5 removals in terms of mass loading and concentration (Table 2). Total mass loadings removals and treatment efficiencies in terms of concentration ranged from 50 to 82 percent and 29 to 79 percent, respectively. Figs. 10 and 11 indicate the trend for BOD_5 total mass loadings removal for the swirl prototype, with Fig. 12 indicating higher removals at the higher BOD_5 influent concentrations.

Table 2. BOD_5 Removal

Storm No.	Mass Loading, kg			Average BOD_5 per storm, mg/l		
	Influent	Effluent	% Rem.	Inf.	Eff.	% Rem.
7-1974	26,545	4,644	82	314	65	79
1-1975	3,565	1,040	71	165	112	32
2-1975	12,329	6,164	50	99	70	29

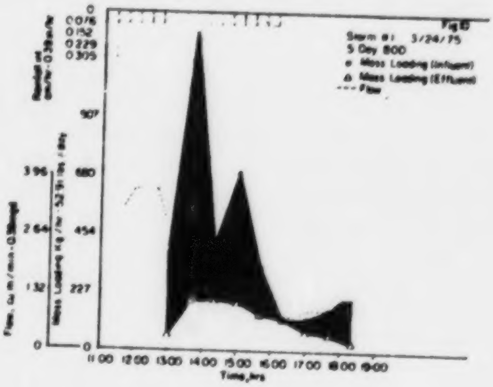


Fig. 10. Swirl Regulator BOD_5 Removals,
West Newell Street, Syracuse, New York

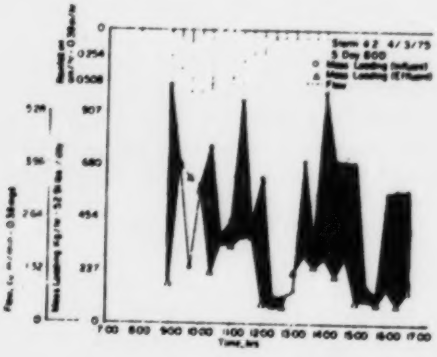


Fig. 11. Swirl Regulator BOD_5 Removals,
West Newell Street, Syracuse, New York

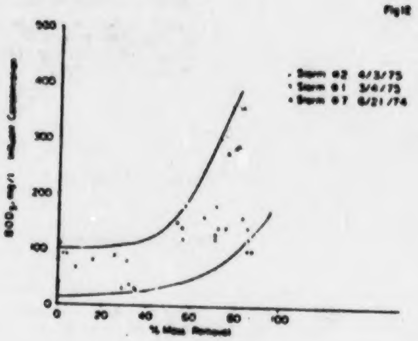


Fig. 12. Swirl Regulator BOD_5 Influent Concentrations vs Percent Mass Loading Removal, West Newell Street, Syracuse, New York

COSTS

Costs for the swirl prototype at West Newell Street, Syracuse, New York (designed to remove 90% grit, without pumping) were $55,000 capital (2,300/cu m/min ($6,100/mgd) and $2,500/ha ($1,000/acre) drainage area) and $2,000/yr operation and maintenance. In addition $13,000 in capital costs were incurred at Syracuse for pumping; if an automatic pipe and nozzle washdown system were installed, it would cost an additional estimated $3,500.

Swirl cost curves (Fig. 13) were developed on the basis of capital costs experienced at Syracuse and full-scale cost estimated for another study.[9] It is assumed that maintenance requirements will be similar for the swirl regulator independent of size and that the person-hour requirements and associated costs will be 88 hrs/yr and $1,800/yr, respectively, as previously stated.

The West Newell Street design matching full-pipe flood conditions could be overly safe for pollution control; especially for larger outfalls. It is entirely possible to reduce capital costs to: $500/ha - $1,250/ha ($200/acre - $500/acre) and $380/cu m/min ($1,000/mgd); in lieu of the thousands of dollars per acre and mgd cost figures used for the $30 billion national estimate for controlling combined sewer overflows (cited earlier in this paper.)

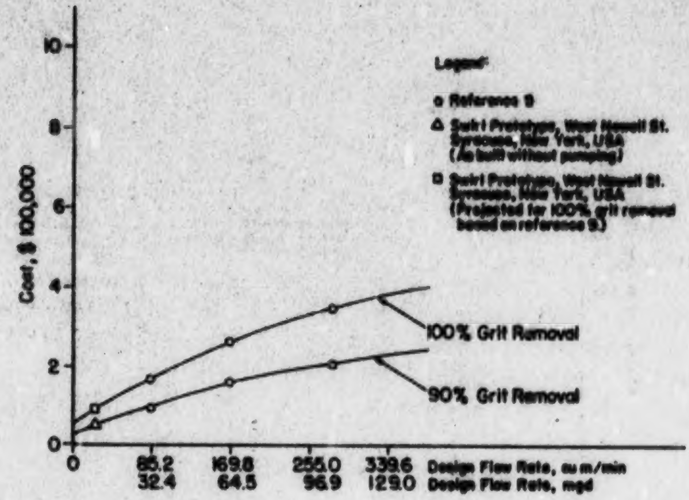


Fig. 13. Estimated Construction Cost Curves—Swirl Regulator/Separator, West Newell Street, Syracuse, New York

SWIRL ADAPTABILITY TO SEPARATE STORMWATER TREATMENT

Swirl devices also offer benefits for erosion control and separate stormwater pollution abatement. A portable swirl has been developed for erosion control using low-cost cattle watering tanks for the "shell."[9] Swirl chambers can be installed on separate storm drains before discharge and the resultant concentrate can be stored in relatively small tanks since concentrate flow is only a few percent of total flow. Stored concentrate can later be directed to the sanitary sewer for subsequent treatment during low-flow or dry-weather periods, or if capacity is available in the sanitary system the concentrate may be diverted to the sanitary system without storage. This method of stormwater control would be cheaper, in many instances, than building hugh holding reservoirs.

CONCLUSIONS

The dual-functioning swirl unit is the first regulator device of its type in the USA to offer the basic advantage of simultaneously controlling the quantity and quality of combined sewer overflow. It is a simple, low cost, and practical facility that can effectively reduce significant portions of grit, settleable solids, BOD_5, and floatables over a wide range of varying overflow rates.

Many combined sewer overflow regulators malfunction or do not give adequate flow control and need replacement. As combined sewer systems are upgraded and improved regulators are constructed to reduce the impact of overflows on receiving water quality, the swirl concentrator must be considered.

There is excellent potential of using the swirl concept for separate stormwater treatment and erosion control.

In many locations additional treatment may be required.

REFERENCES

1. American Public Works Association (1970) Combined Sewer Regulation and Management-A Manual of Practice. U.S. Environmental Protection Agency, 11022 DMU 08/70, Washington, D.C.

2. American Public Works Association (1970) Combined Sewer Regulator Overflow Facilities. U.S. Environmental Protection Agency, 11022 DMU 07/70, Washington, D.C.

3. American Public Works Association (1972) The Swirl Concentrator As A Combined Sewer Overflow Regulator Facility. U.S. Environmental Protection Agency, EPA-R2-72-008, Washington, D.C.

4. Field, R., (1974) Design Of A Combined Sewer Overflow Regulator/Concentrator. Jour. Water Poll. Control Fed., 46 1722.

5. Sullivan, R.H., et al. (1974) Relationship Between Diameter and Heights for the Design of a Swirl Concentrator as a Combined Sewer Overflow Regulator. U.S. Environmental Protection Agency, EPA-670/2-74-039, Washington, D.C.

6. American Public Works Association (1967) Problems of Combined Sewer Facilities and Overflows - 1967. U.S. Environmental Protection Agency, 11020 12/67 (WP-20-11) Washington, D.C.

7. Field, R., and Struzeski, E.J., Jr. (1972) Management and Control of Combined Sewer Overflows. Jour. Water Poll. Control Fed., 44, 1393.

8. Field, R., (1973) The Dual Functioning Swirl Combined Sewer Overflow Regulator/Concentrator. U.S. Environmental Protection Agency, EPA-670/2-73-059, Washington, D.C.

9. Sullivan, R.H., et al. (1975) The Helical Bend Combined Sewer Overflow Regulator. U.S. Environmental Protection Agency, EPA Contract No. 68-03-0272, Cincinnati, Ohio. (At Press)

A REVIEW OF EPA's URBAN RUNOFF POLLUTION CONTROL RESEARCH PROGRAM

It's a pleasure to be here today. I have been working on the urban runoff problem for a few years and have come to recognize the severity of the problem. Without the consideration of potential pollution from stormwater runoff in our municipal and regional abatement plans, there is a good chance that communities could upgrade their dry-weather flow pollution control and still not attain desired water quality.

208 Planning will help to overcome a possible oversight of stormwater pollution. I am hopeful that this seminar will help supply you with the necessary planning tools and concepts for the control of stormwater and combined sewer overflow pollution.

Now I would like to introduce you to the EPA Urban Stormwater Research Program and a Program film entitled, "Stormwater Pollution Control: a New Technology".

The Storm and Combined Sewer Pollution Control Research Development and Demonstration Program was initiated under the U. S. Environmental Protection Agency's (EPA) predecessor, the U. S. Public Health Service, back in 1964. In an early report published in 1964, the nationwide significance of pollution caused by storm-generated discharges was first identified. Congress acknowledged the problem ten years ago by authorizing funds under the Water Quality Act of 1965 for researching ways of stormwater pollution management. The effort is being continued under PL 92-500, and is directed by the Storm and Combined Sewer Technology Program located in Edison, New Jersey and under the Municipal Environmental Research Laboratory of Cincinnati.

Up to the present time, more than 140 projects totaling approximately $100 million have been awarded. EPA's share is about one-half the total, or about $50 million. The present Fiscal Year '76 extramural program budget is approximately $1.0 million.

The Program has two basic facets. The first is problem definition which leads to the second facet--development of effective control alternatives. Program results will be discussed in terms of these two facets.

PROBLEM DEFINITION

The background of sewer construction lead to the present urban runoff problem. Early drainage plans make no provisions for storm flow pollutional impacts. Untreated overflows occur from storm events giving rise to the storm flow pollution problem.

Simply stated, the problem is: When a city takes a bath, what do you do with the dirty water?

Three types of discharges are involved: Combined sewer overflow, storm drainage from separate storm systems, and overflow from infiltrated sanitary lines.

The problem constituents in overflows are: visible matter, infectious bacteria, organics and solids, and , in addition, include nutrients, heavy metals, pesticides and oils.

The average BOD concentration in combined sewer overflow is approximately one-half the raw sanitary sewage BOD. But storm discharges must be considered in terms of their shockloading effect due to their magnitude. Urban runoff flowrates from an average storm intensity of 0.1"/hour are 5 to 10 times greater than the dry-weather flow from the same area. Likewise, a not uncommon rainfall intensity of 1"/hour will produce flowrates 50 to 100 times dry-weather flow. A few municipal studies can serve to exemplify the problem. In Northampton, England, it was found that the total mass of BOD emitted from combined sewer overflows over a two-year period was approximately equal to the mass of BOD emitted from the secondary plant effluent. And that the mass emission of suspended solids in combined sewer overflow was three times that of the secondary effluent. In Buffalo, a study concluded that 20 to 30% of the dry-weather flow solids settled in the combined sewer which was subsequently flushed and bypassed during high-velocity storm flows. In Durham, N.C., with a separate stormwater system, it was shown that an upgrading program to zero discharge without stormwater treatment would still allow 41% of the UBOD and 95% of the suspended solids to enter the receiving water from runoff, and that runoff governs DO levels suppressed below the standard 20% of the time. A generalization from 10 to 12 city studies indicates 40-80% of the total BOD load entering streams comes from runoff and, during storm events, the organic loading from runoff is as much as 94-99% of the total.

CONTROL ALTERNATIVES

The concept of constructing new sanitary sewers to replace existing combined sewers has largely been abandoned due to enormous costs, limited abatement effectiveness, inconvenience to the public, and extended time for implementation.

I will present the viable control alternatives. We can control the problem at the source, e.g. at the land and streets, in the collection system, and off-line by storage. We can remove pollutants by treatment and by employing complex or integrated systems which combined various combinations of control and treatment including the dual use of dry-weather facilities.

Source Control

Source control can be accomplished by employing porous pavement and upstream impoundment for flow attenuation; soil erosion preventative measures; restrictions on chemicals used for de-icing, fertilization, and pest control; zoning and land use regulations, and improved neighborhood sanitation practices.

Sewerage System Control

In sewerage system control, the emphasis is on optimizing the existing collection system. Measures which can be used include:

- Dry-weather flushing to reduce dry-weather solids accumulation and thereby relieving the overflow first flush
- Polymer feed to reduce overflows by increasing pipe-carrying capacity
- Infiltration/Inflow prevention and correction
- Improved flow regulators or diversion devices, e.g. the swirl, helical and fluidic types
- In-sewer or in-line storage and routing whereby the intent is to assist a dispatcher in routing and storing storm flows to make maximum use of existing interceptors and sewer line capacity
- And lastly, the most common approach is off-line or external storage with concrete tanks used often. The concept is to capture wet-weather flow and bleed it back during low-flow, dry-weather periods.

Treatment

The various treatment methods used for stormwater include physical and physical-chemical, biological and disinfection. These processes or combinations of these processes, can be adjuncts to the existing sanitary plant or serve as remote satellite facilities at the outfall.

Integrated Systems

By far the most promising approach to urban stormwater management is the integrated use of control and treatment with an area-wide multidisciplinary perspective.

- Dual-use wet-weather storage and treatment facilities in conjunction with dry-weather plans can be used to improve dry-weather treatment the vast majority of the time when it is not raining. The program has fostered various schemes which reclaim stormwater for beneficial purposes including the enhancement of visual aesthetics, recreation and water supply.
- Land management and non-structural techniques are ways of reducing cost by limiting pollutants to the potentially more costly downstream treatment plans.
- A great deal may be saved by joining the heretofore autonomous agencies and professions involved in flood, erosion, and pollution control. We can cut cost by integrating drainage and reservoir design for flood control with pollution control.

Computer Assistance

Mathematic models are needed to predict complex dynamic system responses to variable and stochastic climatological phenomena. These models have been developed and applied at many levels of sophistication including EPA's Storm Water Management Model (SWMM) which is capable of representing the gamut of urban conditions both qualitatively and quantitatively from the uppermost catchment point to the downstream receiving water.

EPA FILM "STORMWATER POLLUTION CONTROL: A NEW TECHNOLOGY"

The film[1] I am about to introduce portrays a complete overview of the U.S. EPA's involvement in developing countermeasures for pollution from combined sewer overflows and stormwater discharges.

Various countermeasures are shown by the film that are ready for implementation by municipalities. The majority are full-scale operations.

A couple of years ago, we felt that the time was right to make an evaluation of previous Program efforts, and we implemented a contract to develop the state-of-the-art and assess techniques available to manage and treat combined sewer overflow and stormwater. A text[2] on this subject has been completed. Expanding on the cliche, "a picture is worth a thousand words," we felt a film would be worth a hundred thousand--so a film was included as part of the work.

The specific reasons for this film were to alert the environmental engineering and planning community to the stormwater problem and the immediate need to apply available technology to counteract it.

---

[1] "Stormwater Pollution Control: A New Technology", U. S. Environmental Protection Agency. A 16 mm sound-color film available from the National Audivisual Center (GSA), Washington, D. C. 20409 (Prices: Purchase - $119.50, Rent - $12.50)

[2] "Urban Stormwater Management and Technology: An Assessment", EPA-670/2-74-040, U. S. Environmental Protection Agency. Available from the Storm and Combined Sewer Section, Municipal Environmental Research Laboratory, Edison, New Jersey 08817

URBAN RUNOFF POLLUTION DATA BANK

Yesterday the need for retrieval and interstudy transfer of existing data was mentioned along with the need for 208 agencies to join together for this purpose. I would like to advise you that there is an existing EPA R&D project* to compile a computerized urban runoff pollution data resource and retrieval center at the University of Florida at Gainesville under Professors Wayne Huber and Jim Heaney. All data has and is being thoroughly screened for goodness before system entry.

This system will be available to you and I recommend its use as an expeditious focal point for entry and retrievel of data from 208 studies. This will require the cooperation and effort of the 208 agencies, but its potential value should make the effort worthwhile. I will be talking with 208 people in EPA in an attempt to develop a uniform method for this proposal but, in the interim, you are encouraged to contact the University of Florida on your own not only for data retrieval, but I would also hope for data entry as well.

---

* "Collect and Define Availability of Test Data (Rainfall/Runoff) for Urban Models - Data Base," EPA Contract No. 68-03-0496.

URBAN STORMWATER DETENTION AND FLOW ATTENUATION FOR WATER POLLUTION CONTROL

by

Herbert G. Poertner
Engineering and Research Consultant
Bolingbrook, Illinois

DETENTION AND FLOW ATTENUATION

Definitions

"On-site detention" of stormwater generally refers to storage of precipitation runoff excess prior to its entry into a drainage system, followed by gradual release of the stored runoff during and after the peak of the runoff has passed. In some applications, the runoff may first be conducted short distances by collector sewers located on or adjacent to the site of the detention facility. On-site detention is usually differentiated from downstream detention by its proximity to the upper limits of the basin and its use of small detention facilities as opposed to larger dams normally associated with downstream detention.

Use of the terms "detention" and "retention" is often confusing. Detention generally refers to holding runoff for a short period of time and then releasing it to the natural water course where it returns to the hydrologic cycle. "Retention" involves holding some of the water contained in the storage facility for a considerable length of time for aesthetic, agricultural, consumptive, or other uses. Some of the water may never be discharged to a natural watercourse, but it may be consumed by plants, evaporation, or infiltration into the ground.

Detention facilities will not reduce the total volume of surface runoff, but simply reduce peak flow rates by redistributing the runoff over a time period. However, there are exceptions; e.g., the reduced surface runoff volume from land areas that have been contour-plowed, and the reduced surface runoff from detention basins on granular soils.

A comprehensive report entitled "Practices in Detention of Urban Stormwater Runoff"(1) was prepared in 1974 for the Office of Water Research and Technology, U.S. Department of the Interior. This report addresses most aspects of urban runoff detention and presents information obtained in a nationwide study of detention practices.

Concept and Benefits

The concept of temporarily storing, or detaining, excess stormwater runoff and then releasing it at a regulated rate is an important fundamental principle in stormwater management. Storage is extremely important in areas having appreciable topographic relief for the purpose of attenuating peak flow rates and the high kinetic energy of surface runoff. Such flow attenuation can reduce soil erosion and the amounts of contaminants of various kinds that are assimilated and/or transported by urban runoff from land, pavements and other surfaces.

While in storage, the pollutant concentrations in runoff will often be reduced somewhat through natural processes. Before release, the stored runoff may be given further treatment as may be necessary or practical. Finally, by means of controlling release flow rates, the impact of the pollutant loadings of stored runoff on receiving water quality can be minimized, regardless of the degree of treatment provided.

In areas where combined sewers are utilized to transport stormwater runoff, the use of detention facilities can relieve the peak loadings on sewers and treatment plants--thereby reducing the pollution and flooding of basements, streets, land and water bodies. Where storm sewers are used to convey runoff, a system of properly designed detention facilities can also be effective in reducing pollution and flooding from stormwater. In areas of flat terrain where hydraulic gradients are small, detention of runoff can be an important factor in reducing local flooding and in minimizing storm sewer pipe diameters.

Because stormwater detention facilities cause a distinct reduction of runoff velocities, much of the debris and suspended solids transported by runoff flows will settle out. This provides an opportunity to collect the sediments before entering and causing problems in the collection sewer system, treatment facilities or downstream channels and land areas. In some places, it is common practice to provide detention basins for the collection of sediment produced from stormwater runoff.

The use of on-site detention facilities may be dictated by governmental ordinances or may be chosen by a developer, at his own discretion, as a method for reducing costs for drainage facilities. Sometimes detention ponds are built to form the core of blue-green areas in open space developments, parks, and other planned urban developments. Regardless of the reason for the facilities, if they are carefully designed, built, operated and maintained, the result is the same--"attenuation of peak runoff flow rates". Many fringe benefits, not identified above, can result as a by-product of on-site detention.

Generally, detention storage may be provided in one or a combination of different locations: (1) on, or near, the sites where the raindrops fall; (2) in stormwater collection and conveyance systems; or (3) in downstream impoundments.

The remainder of this paper deals with various means for detaining excess stormwater runoff, both above the ground surface and underground.

STORMWATER DETENTION METHODS AND APPLICATIONS

Underground Storage Versus Aboveground Storage

Underground storage of stormwater runoff usually involves transporting the excess runoff in sewers or channels prior to storage. The storage facilities must sometimes be located away from the site where the runoff is generated and collected. In this respect underground storage differs from aboveground storage that may be provided on rooftops of buildings and parking lots, and in basins or ponds located within land development sites or open space areas. However, for both underground and aboveground storage, the goals are the same, generally--to control water pollution and flooding of land and property. Corollary goals are to protect and enhance natural resources, urban environments, public health, and social and economic values.

The concept of attenuating peak flow rates in sewer systems and other flowways, prior to treatment or release of wastewaters, is also the same for both underground and aboveground storage. The principal advantage of underground storage as compared to aboveground storage in urban areas is the better availability and lower cost of space for storing large volumes of stormwater runoff or combined sewage. Aesthetics, health factors, environmental considerations and economic and social objectives may also be better served by underground storage facilities.

Aboveground storage of excess stormwater runoff presents some advantages not inherent in underground storage systems. Foremost are the lower operating and maintenance costs possible with aboveground storage and the greater opportunities afforded for multiple-purpose use of facilities--especially wildlife preserves, recreation and landscape enhancement. In some places, it may be feasible to divert stored runoff by gravity flow for land irrigation and for supplementing local raw water supplies. In either aboveground or underground storage, stormwater excess may be used under favorable conditions for recharging ground water supplies.

Regardless of how, or where, stormwater runoff or combined sewage is collected and detained, the important consideration is that it has been isolated and captured! This makes feasible the best practical methods for its further handling to minimize pollution and flooding. For example, if treatment is selected, the stored runoff or combined sewage may be released to treatment facilities at flow rates that are compatible with treatment plant capacities. Or, if flooding caused by high rates of runoff into the stormwater drainage system is a problem, the peak flow rates can be controlled to reduce the flooding impacts.

Basins and Ponds on Ground Surfaces

Usually, retention ponds and detention basins constructed on ground surfaces are relatively large, covering several acres. The design of such facilities will vary depending upon land costs, space availability, phsical and aesthetic characteristics of the area, topography, climate, hydrologic conditions, and other local factors. Whether or not a detention facility is to serve multiple-purpose uses is a factor that may dictate size, shape, depth, landscaping treatment and whether it will be designed to retain a minimum depth of water. For example, a retention pond may be designed with special features to serve as a recreation pond for boating and fishing. Such a facility would require different design criteria than a basin which is to fulfill the single purpose of stormwater detention. In other instances, the availability of large open areas will permit a design having gentle side slopes and extensive landscaping; while sites where land is limited might dictate deep ponding areas, pumped discharge, and steep side slopes that require fencing and other security measures to minimize safety hazards.

Detention basins are sometimes used to collect eroded soil and debris for later removal and disposal. Sediment collection basins are frequently used during periods when land development operations are underway. The purpose is to intercept eroded soils, debris and their associated contaminants to preclude their entry into sewer systems and water bodies. This technique can be an important factor in reducing blockage of flows in drainage systems and treatment facilities and to reduce the pollutant loadings from surface runoff and storm sewer discharges.

Both the State of Maryland and Fairfax County, Virginia have programs to control sediment using detention ponds. The topography of these areas is steep, and stormwater runoff can quickly cause problems of erosion and sedimentation if suitable precautions are not taken. Ponds are used during construction periods and after development. Maryland's program was started in the 1930's(2). In 1970, the Montgomery County Soil Conservation District adopted a resolution to encourage and assist in the planning of stormwater drainage, utilizing the greatest amount of detention considered feasible. In 1970, the State enacted the Sediment Control Law which required all countries to implement the law by March 1, 1971.

At the present time, there are over 175 permanent detention ponds in Montgomery County. Acceptance of the concept is not universal, although complaints have not been severe enough to take the matter to court. Three main objections to the program have arisen. One is that responsibility for maintenance of these ponds is still being debated. Another major objection is the lack of knowledge concerning the usefulness of the detention concept. The argument is that the long-term effect of such storage is not known, and that corollary disadvantages may outweigh the gains. The third major criticism concerns the legal status of the requirement. Although the legal counsel of the State and Montgomery County have offered their opinions that such measures are legal, without a court testing of these opinions,the legal status is actually unresolved. However, the complaints against on-site detention storage have not yet become so serious as to cause a developer or land owner to take the matter to the courts. Even though there is some opposition to the on-site detention concept on a short-term basis, the method is seen to be effective for controlling this major pollution problem. Stormwater detention facilities are especially popular as a temporary measure during construction; however, they are also useful for permanent solution of erosion, sediment and pollution problems, as well as flood control.

Parking Lot Storage

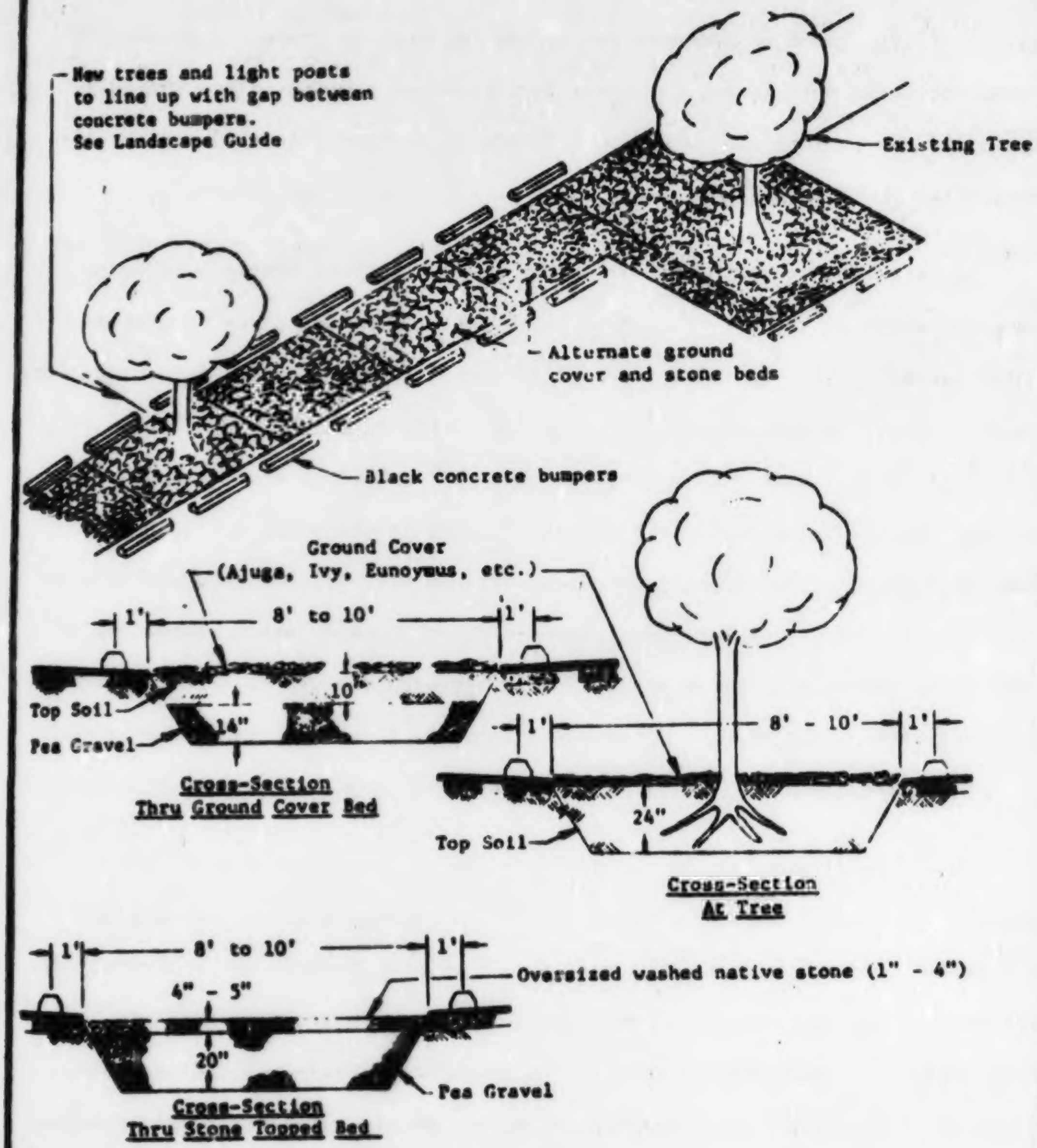
Temporary storage of stormwater on parking lots is another means employed to reduce runoff rates and sewer loading. Unlike ponding on rooftops, there is no limit, from a structural standpoint, to the depth of water that can be stored. Another advantage is that the surface does not need to be dead-level as is true in the case of rooftop ponding. Because of the ease of inspection and access, the maintenance and operation of parking lot detention facilities is a low cost item and easy to perform with mechanical street cleaning equipment.

There are two general forms of stormwater detention on parking lot surfaces. One form involves the storage of runoff in depressions constructed at drain locations. The stored water is drained into the sewer system slowly, using restrictions, such as orifice plates, in the drain. Proper design of such paved areas would restrict ponding to areas which will cause the least amount of inconvenience to the users of the parking areas. For example, the parking lot of a shopping center would have the ponding areas located in the least-used portions of the lot, allowing customers to walk to their vehicles in areas of no ponding except when the entire lot is filled with vehicles. Drainage of ponded water would be fairly rapid as compared to rooftop ponding to prevent customer inconvenience. In most cases, the water would pond to a depth not to exceed 12 inches and the ponding area would most likely be drained within 30 minutes, or less, after the rainfall.

Another type of stormwater detention on parking lots consists of using the paved areas of the lot to channel the runoff to grassed areas or gravel-filled seepage pits. The flow then infiltrates into the ground. Soil conditions and the effects of siltation in reducing infiltration must be considered. As an example of this method of detention, Miles Laboratories, Inc. has developed parking lots utilizing a pervious median strip to handle storm drainage as shown in Figure 1, Parking Lot Details. Designs of this type reduce construction costs of the drainage system because smaller diameter storm sewers can be used. Such median strips are aesthetically pleasing and can be used for storage of plowed snow in the winter. The possibility of polluting ground water should be investigated, particularly if no confining soil strata is present.

The large area which is characteristic of many parking lots serving shopping centers, office buildings, apartment complexes and industrial plants is a factor that makes such parking lots extremely attractive for stormwater detention. In one application at an apartment complex in Boulder, Colorado, paved portions of the parking lot and the grass areas between buildings were dished to store runoff for regulated, slow release through sewer inlets provided with steel orifice plates. Large volumes of rainfall and snowmelt can be stored in this manner with little personal inconvenience.

A parking lot drainage system incorporating detention can often be constructed at a cost below that for a conventional design. For example,


New trees and light posts to line up with gap between concrete bumpers. See Landscape Guide
Existing Tree
Alternate ground cover and stone beds
Black concrete bumpers
Ground Cover (Ajuga, Ivy, Eunoymus, etc.)
1'
8' to 10'
1'
10"
Top Soil
14"
Pea Gravel
Cross-Section Thru Ground Cover Bed
1'
8' - 10'
1'
24"
Top Soil
Cross-Section At Tree
1'
8' to 10'
1'
Oversized washed native stone (1" - 4")
4" - 5"
20"
Pea Gravel
Cross-Section Thru Stone Topped Bed

details of median strip for parking lot drainage

Source: Miles Laboratories, Inc.
Building Construction Standards

FIGURE 1. PARKING LOT DETAILS

Consolidated Freightways, Inc. used stormwater detention techniques in constructing a parking area and storm sewers at its truck terminal in St. Louis, Missouri. The $ 115,000 cost of the drainage system constructed was $ 35,000 below the estimated $ 150,000 cost of a system without provisions for on-site detention.

If porous pavements are used extensively in the future in parking lot construction, large volumes of rainfall can be made to seep into the ground instead of being discharged into sewers or streams. This can be an important corollary advantage of stormwater detention facilities in water-short areas. Climate, soil conditions and the possibility of polluting ground water supplies must be considered in the planning and design of such facilities.

Rooftop Detention

Horizontal rooftops are used in some places for stormwater detention. Rooftops can provide storage which will not inconvenience pedestrians or motorists. A rooftop detention facility is not unsightly because it is not visible, and it is not a safety hazard to children. However, rooftop storage is not a problem-free method as there are problems of leakage, possible structural overloading, maintenance for removal of debris and ice and the possiblity that heavy rainfalls will overflow the top of the roof if drains become blocked. This could result in serious damage to the building and its contents.

These problems can be minimized by proper design, especially if detention is designed into the original building plans and not provided later as an afterthought. For example, leakage problems can be reduced by adding extra layers of roofing membrane and by taking special care in installing roof flashings to make a watertight seal. Structural design should not be a problem in northern climates, as building codes currently specify adequate strength for snow loadings, usually 30 to 40 pounds per square foot. With the weight of water being

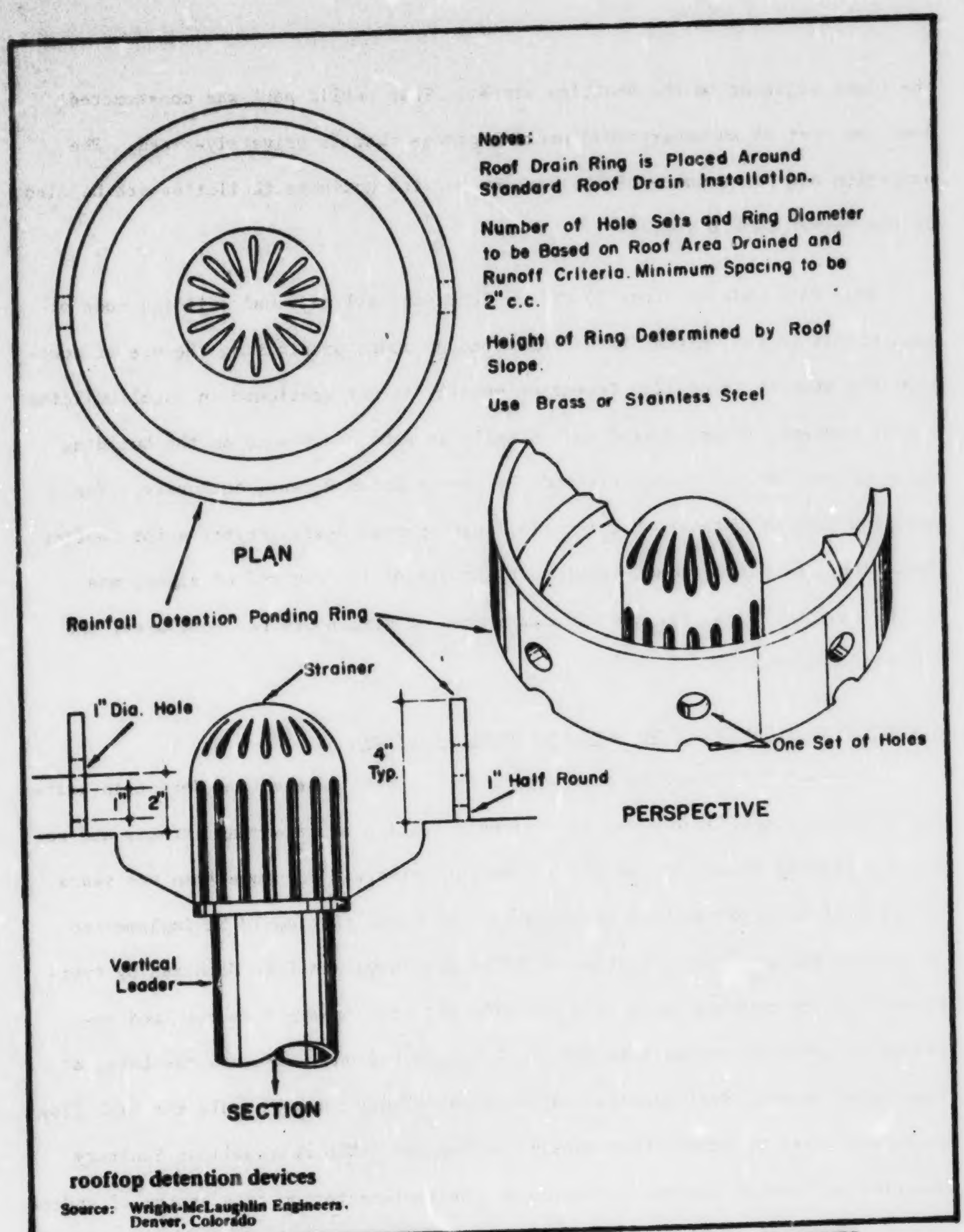
62.4 pounds per cubic foot, a properly designed roof will have the structural strength to handle almost 6 inches of water depth , an amount that is more than sufficient for fulfilling the requirements of on-site detention of rainfall.

Maintenance is a bit more difficult and will require periodic attention, especially in the autumn during and after the leaf-falling season. However, all horizontal roofs in urban areas would need such maintenance and the added effort to maintain a roof designed to detain rain water should not be unreasonable. In many cases, the roofs will be sufficiently high or the buildings will be located in areas where maintenance would not be a problem, because debris would not accumulate enough to cause a blockage of the roof scuppers, gutters or rain leaders.

The possibility of overflows is present with any roof structure, although it is more likely when stormwater is stored on the roof. One alternative usually required by building codes is the use of overflow drains and scuppers in the parapet wall, usually about four inches above the roof drain. Proper maintenance and periodic inspection will reduce the possibility and the hazards of overflows.

The recently-completed 25-story office tower constructed for the Prudential Insurance Company in the Skyline Urban Renewal area was designed to detain rainfall on its roof and in plaza areas. A specially designed rainfall ponding ring designed by a local engineering firm was installed surrounding each roof-drain conductor head. It is designed to operate in accordance with drainage criteria of the Denver Urban Renewal Authority (DURA). Engineering details of the ponding ring are given in Figure 2.

The Park Central Bank and Office Complex recently constructed in the Skyline area incorporates rooftop ponding and ponding in arcades. Detention ponding is also being provided in the depressed parkway extending along one side of


PLAN
Rainfall Detention Ponding Ring
Strainer
1" Dia. Hole
1"
2"
4" Typ.
1" Half Round
Vertical Leader
SECTION
PERSPECTIVE
One Set of Holes

Notes:

Roof Drain Ring is Placed Around Standard Roof Drain Installation.

Number of Hole Sets and Ring Diameter to be Based on Roof Area Drained and Runoff Criteria. Minimum Spacing to be 2" c.c.

Height of Ring Determined by Roof Slope.

Use Brass or Stainless Steel

rooftop detention devices

Source: Wright-McLaughlin Engineers. Denver, Colorado

FIGURE 2.RAINFALL DETENTION PONDING RING FOR FLAT ROOFS

the block adjacent to the abutting street. This public park was constructed over the roof of an underground parking garage that is privately-owned. The operation and maintenance of the parkway and its drainage facilities are handled by the Denver Park District.

Inquiries made of about 25 major cities and all national building code organizations in the United States uncovered no codes prohibiting the use of rooftops for storing rainfall. Detention usually is not mentioned in local building codes; however, it is covered specifically in some codes such as the building codes of New York City, Detroit and the Denver Urban Renewal Authority. The building code of Detroit, Michigan includes special design criteria for rooftop detention, including: a dead-level roof, provision for control of algae, mosquitos and other insects, the minimum number of downspouts per roof area, and the roof drainage rate.

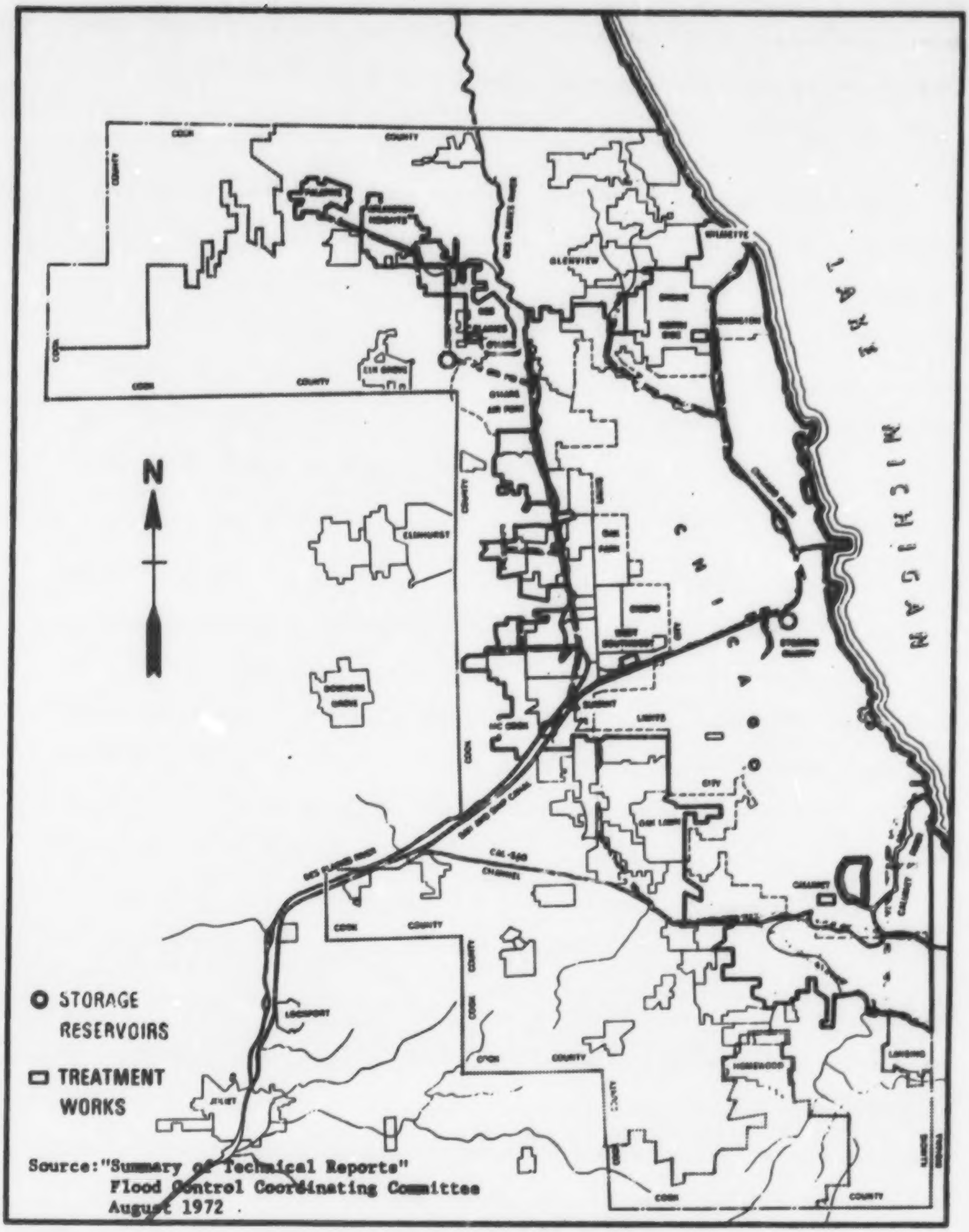
Abatement of Pollution from Combined Sewer Overflows

In areas having combined sewers, there is much interest in detention storage of urban runoff as a means of abating pollution of receiving streams and reducing flooding caused by overflows from such sewers. For more than ten years the city of Chicago has been studying various means that could be implemented to prevent the periodic pollution of local waterways and Lake Michigan by overflows from its combined sewer system. The pollution comes from required releases of combined sewage into the local waterways, and sometimes the Lake, at times when sewers, drainageways and treatment plants cannot handle the high flow rates generated by runoff from intense rainstorms. The Metropolitan Sanitary District of Greater Chicago is beginning the implementation of a system of underground storage of combined sewage.(3) The $ 1.5 billion project involves the construction of 125 miles of large-diameter tunnels and reservoirs for temporary storage and conveyance of combined sewage in Silurian Dolomite rock formations at depths of 150 to 290 feet below the surface of the waterways. Tunnel diameters, ranging between 10 feet and 42 feet, will receive flows from 640 sewer overflow points in the 375 square mile area served by the system. Figure 3 highlights the Tunnel And Reservoir Plan.

During periods when the collection sewers and interceptor sewers are overloaded and the capacity of the three existing treatment plants are over-taxed, the combined sewage will be diverted from interceptor sewers through vertical shafts to the tunnels. Later, when the sewage flows diminish below surface sewer capacities and the treatment plants are capable of treating the flows, the stored mixture of sewage and stormwater will be pumped to one of three new surface reservoirs for detention and subsequent release at predetermined rates to the wastewater treatment plants.

The primary reservoir facilities are located in the area now occupied by the sludge lagoons of the Metropolitan Sanitary District in the McCook-Summit area. Excavation is to be performed by the quarry method. The reservoir will be 330 feet deep, 500 to 1200 feet wide and 2.5 miles long. It will be divided into three basins with a total storage capacity of 57,000 acre-feet below Elevation-100, Chicago City Datum. Although the Chicago Tunnel and Reservoir plan is not truly "on-site" detention, as previously defined, the goal and concept is similar. The primary objective is to abate pollution of receiving waters and real property, and reduce local flooding, by means of attenuating peak flows in the sewers and surface drainage system.

Combined sewers serve 24,000 acres of the City and County of San Francisco, with systems of interceptors delivering sanitary wastes to three existing sewage treatment plants. To control the pollutants discharging to San Francisco Bay and the Pacific Ocean, a master plan has been developed by the city and county based upon several years' studies.(4) The objectives of the Master Plan are the


LAKE MICHIGAN
CHICAGO
N
STORAGE RESERVOIRS
TREATMENT WORKS
GLENVIEW
WILMETTE
ELMHURST
DES PLAINES RIVER
CAL-SAG CHANNEL
LOCKPORT
JOLIET
HOMEWOOD
COOK COUNTY
CITY

Source:"Summary of Technical Reports"
Flood Control Coordinating Committee
August 1972

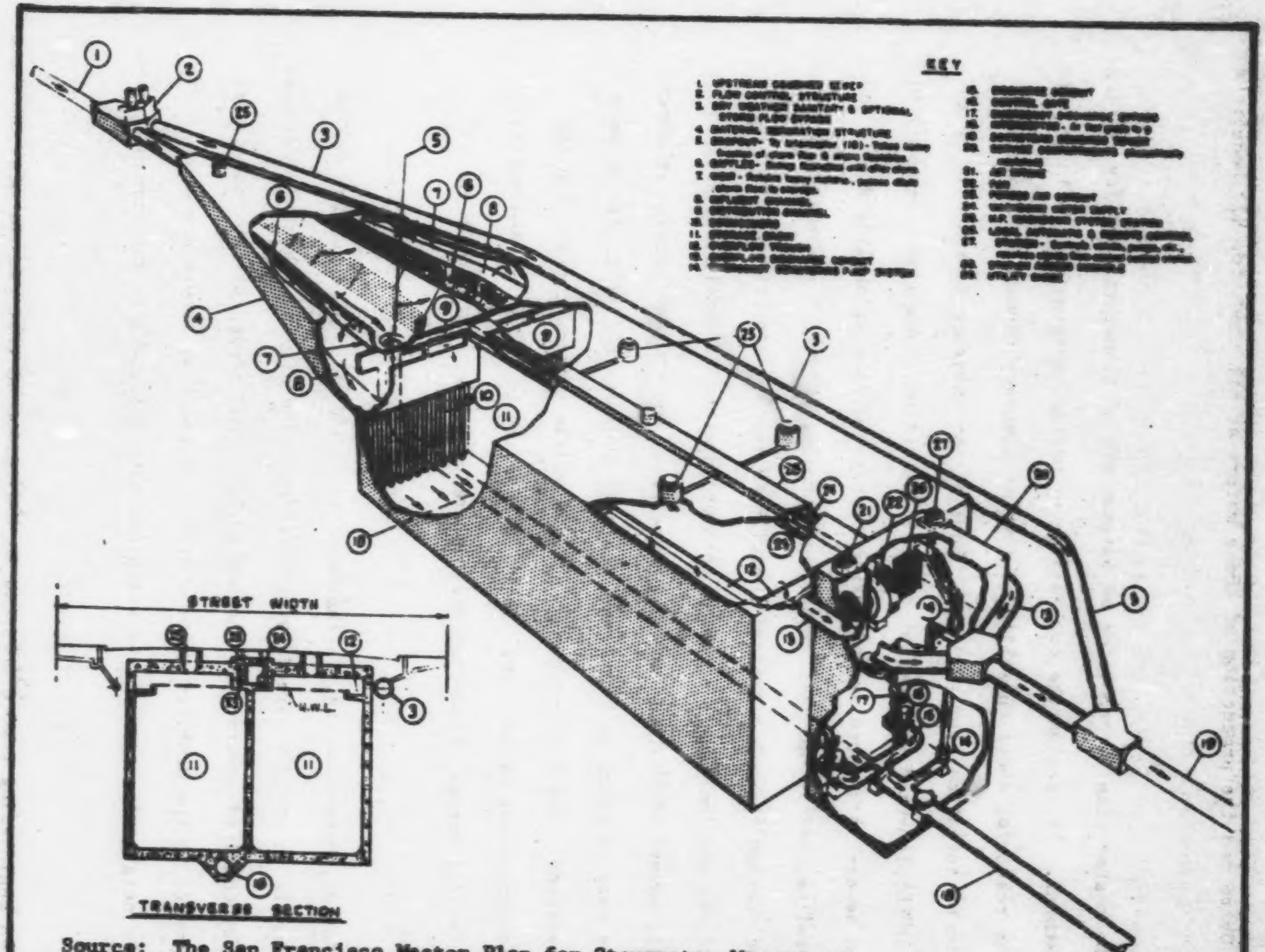
FIGURE 3. CHICAGO TUNNEL AND RESERVOIR PLAN

preservation and enhancement of the quality of the waters of the Bay and the Pacific Ocean and the protection of these waters at all times for all beneficial uses.

The master plan incorporates an optimum mix of transport capacity, storage, and treatment. It retains the combined sewer system, up-grading the inadequate sewers by restoring about one-third of them to adequacy through the judicious selection of detention storage sites. Some of the existing sewers will be replaced or supplemented with relief sewers. Detention storage of stormwater and combined sewage is planned in underground concrete tanks at shallow depths near the shoreline, and in upstream basins and tunnels. Figure 4 presents a perspective and section through a typical shoreline detention structure. The tunnels are designed and located to serve as both storage and transport facilities. This will permit controlled interchange of flows and storage between sub-watersheds as varying storm patterns over the area overtax the facilities of some sub-watersheds. The master plan proposes a single treatment plant (in the southwestern corner of the City) having a capacity of 1,000 mgd and outfalls to the Pacific Ocean. Financing and implementation schedules must yet be arranged.

Boston, Massachusetts, is another city which has considered the use of deep tunnels to store combined sewer overflow. The city has about 7,000 acres served by combined sewers plus another 10,000 acres served by separate sewers that connect to the combined sewer system. In addition, there are about 6,700 acres in neighboring communities which are also tributary to the combined sewer system.

An engineering report(5) prepared in 1967 proposed that, in the area of separate sewers, the stormwater should be diverted to separate outflows where feasible.


KEY
1. UPSTREAM COMBINED SEWER
2. FLOW CONTROL STRUCTURE
STREET WIDTH
H.W.L.
TRANSVERSE SECTION
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27

Source: The San Francisco Master Plan for Stormwater Management

FIGURE 4. INLAND BASIN PERSPECTIVE
San Francisco, California

In the areas where this is not feasible, estimated at 3,300 acres, the stormwater runoff should continue to flow into the combined sewers. A deep tunnel was proposed for the outflows of Boston's combined sewers plus the outflow from the combined sewers of four neighboring communities. Total area tributary to the deep tunnel plan would be 17,000 acres.

The deep tunnel plan was selected over three alternative plans. Construction cost estimates based on 1967 prices, were found lower for the tunnel plan. Although part of the decision to recommend the system was based on cost, other factors included land requirements and adequacy of the system to perform under severe conditions. From a cost standpoint, it is thought that the deep tunnel plan should be more economical(percentage-wise) now than it was in 1967. The plan has been approved by the City of Boston and the Commonwealth of Massachusetts. Figure 5 highlights the plan.

The tunnel system will be able to handle a 15-year rainfall event of five inches of rainfall in 24 hours without surcharging,and an 8.4-inch, 24-hour rainfall (the maximum recorded in Boston) with surcharging of the tunnel. Rainfalls in excess of 8.4 inches in a 24-hour period are possible, but the sewer system in Boston is unable to carry more than this amount of rainfall.

It was proposed that 17.2 miles of 33-ft diameter tunnel be constructed along with a pumping system capable of handling 2,400 cfs under normal conditions; and 5,200 cfs under the conditions of surcharging-caused by the 8.4-inch, 24-hour storm cited. If a short outfall is utilized, these pumps would be able to handle larger rains than the maximum recorded. The proposed outfall would be a 20-ft diameter pipe extending 45,000 feet out to sea, where the combined sewage and stormwater would be discharged through diffuser piping giving a minimum of 200 to 1 dilution, which was deemed adequate to meet water quality standards. Implementation of the plan is uncertain at present.

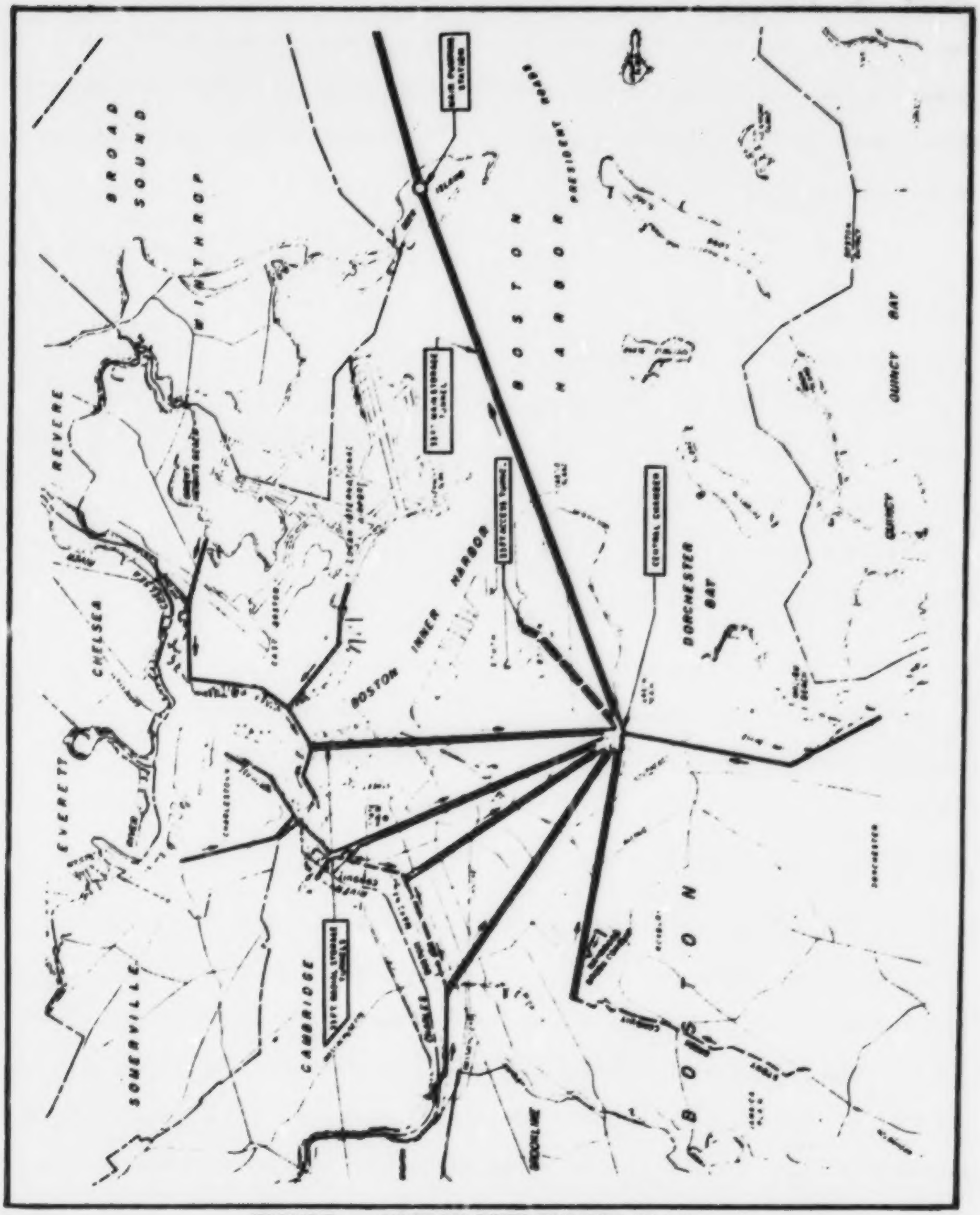

BROAD SOUND
WINTHROP
REVERE
CHELSEA
EVERETT
SOMERVILLE
CAMBRIDGE
BOSTON
BOSTON INNER HARBOR
BOSTON HARBOR
PRESIDENT ROADS
DORCHESTER BAY
QUINCY BAY
BROOKLINE
DORCHESTER
CENTRAL CHAMBER

FIGURE 5. BOSTON DEEP TUNNEL PLAN
Source: "Improvements to the Boston Main Drainage System
Camp, Dresser & McKee, Inc, 1967

Some cities and metropolitan areas in the United States have initiated "in-system storage" techniques for minimizing water pollution and flooding from combined sewer overflows. The Municipality of Metropolitan Seattle has instrumented the combined sewer system serving the City of Seattle. The computer-control system, known as CATAD (Computer Augmented Treatment and Disposal), regulates flows through the West Point trunk sewers and interceptors. The flows of combined sewage are regulated to take advantage of excess storage capacity available at various sections of the sewer network during heavy flows produced by rainstorms. This prevents frequent overflows of untreated sewage into Lake Washington, the Duwamish River and Puget Sound.

The Metropolitan Sewer Board serving the Minneapolis-St. Paul metropolitan area of Minnesota has also implemented a computer control system for monitoring sewage flows in its combined sewer system. The purpose is to minimize pollution from sewage overflows by optimizing the storage capacity of the sewers.

Other jurisdictions have successful programs for minimizing overflows from combined sewers, as well as separate sanitary sewers. For example, the Springfield Sanitary District, serving Springfield, Illinois initiated a campaign in 1960 asking citizens to remove connections of roof drains from both combined sewers and sanitary sewers. The purpose was to relieve backups of sewage into basements of residences and business buildings. The program, based on voluntary citizen cooperation, was extremely successful and was accomplished at a very low cost to the community. Ironically, this program is not an example of pollution control by detention methods; rather, it is the reverse of detention. It is illustrative of how pollution of citizens' property was reduced by removing the cause of unwanted storage of wastewaters in basements. A detailed account of the Springfield program was published in 1969 in the Journal of the Water Pollution Control Federation.(6)

Some other cities have programs similar to Springfield's, and a few, such as Bensenville, Illinois, in Cook County, have also required removal of connections of foundation drains to sewers.

In all of the examples given in this section, the control methods vary but the goal and concept is the same for each--namely, abatement or reduction of pollution and flooding by flow attenuation in sewers and drainageways.

PLANNING AND DESIGN OF DETENTION FACILITIES

Planning and Impact Analysis

It is important that planners and designers of stormwater detention facilities give careful consideration to identifying and evaluating the probable impacts of the completed facility. Such impacts can be classified broadly as social, economic, political and physical (environmental and ecological). Both planners and designers can influence the positive or negative aspects of these impacts by their evaluations of available alternatives and decisions made during the design process. It seems prudent that they give special attention to consideration of the following:

(a) safety of people and wildlife,

(b) protection of real property, wildlife habitats, and natural resources,

(c) environmental enhancement of the local area,

(d) multiple-purpose use of facilities,

(e) lowest annual cost of the facility that is attainable within project constraints and community goals, and

(f) cooperation with adjacent communities and governments to promote a watershed approach to providing stormwater management.

Engineering Design

There are six major design determinations involved in the engineering design of stormwater detention facilities. These are: (1) the selection of a "design rainfall event", (2) the volume of storage needed, (3) the maximum permitted release rate, (4) pollution control requirements and opportunities, (5) identification of practical detention methods and techniques for the specific project, and (6) selection of method(s) and technique(s) to be adopted, in view of effectiveness, legal requirements, costs and availability of financing. Some of these design considerations will be discussed briefly in the following.

The design rainfall event most often used was reported in a survey made in 1972 by the American Public Works Association (APWA) to be that having a 10-year recurrence interval. The second most common design rainfall used was given as the 15-year frequency. A few responses indicated the use of design rainfalls of less than the 10-year event while others indicated use of the 100-year frequency, or greater, for design. Many engineers stated that their choice of design rainfall frequency for a specific project is determined solely by the requirements of the local public agency having jurisdiction.

The storage volume need for the design rainfall event is given by the maximum difference, at any time, between cumulative total inflow volume and cumulative outflow volume, starting with the beginning of inflow. This required storage capacity can be calculated using established principles and techniques regularly employed by hydrologists. The survey pointed out that a wide variety of methods are used to determine the storage volume to be provided, depending upon local circumstances. Runoff predictions are most often based on unit hydrographs and the Rational Formula. The basic consideration is to provide enough storage to prevent runoff rates from causing downstream flooding with a goal of limiting the future runoff flow rate to the historic rate. But, compromises are frequently made for reasons of economy or land availability.

Representatives of some engineering firms reported that they design detention facilities to store a specific precentage of peak runoff flow. Many firms reported that storage volume requirements are determined from provisions of local legislation or administrative directives. For example, the Metropolitan Sanitary District of Greater Chicago requires that the 100-year rainfall be used in design and has established a formula for the volume of storage required.

Some engineers have found that the practical storage volume is dictated by the multi-purpose uses planned for the detention facility. A parking lot, for example, could be used for storage to a water-depth of only about 8 inches before it becomes incompatible with its primary use. Similarly, the variations of water-depth in park ponds must often be limited to improve aesthetics, facilitate recreation uses, and provide a suitable habitat for fish.

The basic design factor used in determining the maximum release rate of stored runoff is the ability of the downstream sewers or stream channels to handle the flow satisfactorily without adding to erosion, sedimentation, drainage or flooding problems. Often, this rate is based upon consideration of the expected future runoff from the watershed after planned land development takes place. Or, the maximum release rate may be limited so as not to exceed the natural flow rate of the receiving sewers and streams that prevailed before land in tributary watershed areas was developed.

In many cases, the limit on release rates is specified by local ordinances and regulations. Such laws and regulations may be based upon the flood hazard characteristics and economic characteristics of specific watersheds. In all cases, the selection of the maximum release rate should be based upon controlling erosion, pollution and flooding downstream from the detention facility without causing a serious problem at the facility itself. For example, a detention basin in a busy parking lot should be drained faster than a detention pond or basin in a park because of the greater inconvenience that the flooded parking lot would cause for many people if it were drained slowly.

Control methods reported in use for release of the detained water include weirs, spillways, orifices, hydraulically limited outlets and control gates, in that order of popularity. Control gates were the least popular, it was found, due to the need to adjust them for proper control of each rainfall event.

The prevailing viewpoint of representatives of local public agencies having jurisdiction over stormwater management in urban areas is that detention facilities should be designed and constructed with storage capacity sufficient to enable limiting the rate of runoff from the developed land area to the rate that prevailed before development. Many local jurisdictions have adopted legislation requiring this in new land developments. Land availability and topography are often limiting factors, along with economic considerations, that influence decisions regarding detention methods and techniques. In all cases, the pollutant assimulating capacity and the hydraulic capacity of the receiving drainage system below the detention facility is a factor that must be considered in determining the amount of storage necessary.

OPERATION AND MAINTENANCE

The operation and maintenance of stormwater detention facilities is an important factor in determining the effectiveness of the facility and its acceptability to the public. Poor operation and maintenance not only reduces the usefulness of detention storage, but can cause the facility to become an eyesore, nuisance or health hazard. When stormwater detention is weighed against other methods of runoff control, maintenance and operation is usually viewed as the most difficult problem and the factor most often mentioned against the use of this method. This was revealed by the surveys made by the APWA in 1972, the results of which are discussed next.

The answers to inquiries made of public agencies and engineering firms clearly underline the importance of operation and maintenance difficulties. In each of these surveys, a question was asked to solicit the respondent's evaluation of all the various possible factors that might be considered to constitute a problem or an adverse condition that would be viewed as a disadvantage of stormwater detention. Table 1, Apparent Adverse Factors, includes tabulations of the responses of representatives of the public agencies and engineering firms which responded to this question.

TABLE 1

APPARENT ADVERSE FACTORS OF ON-SITE DETENTION

(a) As Seen by Public Agencies

Factor	No. of Agencies Reporting	
	Yes	No
Aesthetics of empty ponds is poor	101	61
Mosquito breeding would increase	107	56
Algal growth would occur in shallow ponds	108	48
Operation difficulties exist	81	69
Ponds are a safety hazard to children	92	54
Other adverse effects are foreseen	18	5

(b) As Seen by Engineering Firms

Factor	No. of Firms Responding	
	Yes	No
General maintenance and operation	31	2
Sedimentation	26	7
Safety of children	23	8
Safety and/or property loss from dam failure	21	10
Mosquito breeding	16	15
Aquatic vegetation	14	16
Other	9	3

Source: 1972 Survey by the American Public Works Association

From Table 1a, it is noted that 54 percent of the public agency respondents feel that operation difficulties exist in connection with on-site detention of runoff. About two-thirds of these respondents consider that significant problems would be encountered with aesthetics, mosquito breeding, algal growth, and safety hazards. Table 1b shows that most design engineers feel that significant problems would be encountered with general maintenance and operation, particularly in the areas of safety of children, property loss from failure of dams, and sedimentation. About one-half of the engineers are concerned about mosquito breeding and growth of aquatic vegetation.

These tables show the concern of public officials and design engineers for problems of maintenance and operation, but they give no indication of the seriousness of the problems. Although the responses concerning the adverse effects of detention might indicate that these disadvantages could make stormwater detention an unworkable method, the successful use of detention storage shows that these problems are not sufficient in themselves to eliminate the method as a practical solution to problems of urban stormwater runoff management.

IMPLEMENTATION SUGGESTIONS

The following suggestions are presented to serve as a guide to public agencies in planning, designing and implementing various types of stormwater detention facilities and programs, and stormwater management programs in general.

1. Determine the extent of stormwater pollution, drainage and flooding problems.

2. Estimate the future extent of these problems.

3. Determine the existing water quality, hydrologic and hydraulic features.

4. Develop a set of goals and objectives for meeting present and future requirements imposed by federal, state and local authorities.

5. Develop a master plan for action:

This plan should consider the alternative methods of stormwater management available, future urban growth in the jurisdiction involved (and in the entire watershed), and possible future uses and/or treatment of stormwater runoff. The compatibility of elements of the stormwater management plan with goals and objectives of all water resource management agencies having jurisdiction in the area should be investigated and differences should be reconciled where possible.

6. Adopt a regional approach for solving and preventing the problems of erosion, pollution, drainage and flooding. Otherwise, the solutions of one community can make additional problems for another community. A drainage district, sanitary district or environmental control agency would be suitable for implementation of regional plans. State-enabling legislation may be required to set up a regional authority.

7. Develop design criteria along with the development of a master plan for stormwater management.

8. Develop a detailed plan utilizing the design criteria.

9. Enact legislation to carry out the goals of the chosen solutions to meet the design criteria, and to fit into the detailed plan.

Suitable legislation might include:

(a) Ordinances pertaining to stormwater pollution control to protect the water quality of receiving streams,

(b) Laws requiring stormwater detention on roofs of new or existing buildings, parking lots, and open spaces of new land developments,

(c) Laws requiring removal of connections of roof drains from the public sewer system.

(d) Flood-plain zoning laws, and

(e) Flood-proofing regulations for buildings in flood plains.

10. Develop a financing and construction implementation strategy.

11. Prepare engineering designs.

12. Carry out the plan, allowing for future developments which may offer or require new approaches.

13. Update the plan at regular intervals of time.

14. Keep citizens informed of: progress being made, ways in which the stormwater management program is benefiting people in the area, how they can help, and future plans.

CONCLUSIONS

The major benefits that can be derived from properly operated urban stormwater detention facilities are the reduction or abatement of water pollution and downstream flooding. Because soil erosion produced by stormwater flows diminishes with reduced runoff rates, an important benefit attributable to detention is the reduction in the pollution of receiving streams by contaminants in suspended solids and sediment.

Public officials should enact on-going programs to help people develop a better understanding of the necessity for man to cooperate with the forces of nature instead of fighting them. Public officials, planners and engineers should be made aware of the need to attenuate peak runoff flow rates by one method or another. This usually requires the provision of storage space for the runoff that inevitably results from most rainstorms and melting snow. People ought to be convinced that land developments in metropolitan areas should be guided, in part, by decisions concerning water pollution abatement, soil erosion, stormwater drainage and flood control.

Regardless of what decision is made regarding stormwater management, there results a "selection-of-space for the temporary storage of runoff". The significance of this important action, or inaction, is given insufficient attention in planning and design. If no provisions are made to transport stormwater, it may occupy space near the place where it falls. If a storm sewer is constructed, excess stormwater runoff will occupy space in the sewer network and at the downstream end of the storm sewer. Without advance planning and thoughtful engineering, the water may occupy space and cause pollution problems in basements of buildings, highway underpasses and other urban places.

ACKNOWLEDGMENTS

The work upon which this paper is based was supported in part by funds provided by the United States Department of the Interior as authorized under the Water Resources Research Act of 1964, Public Law 88-379, as amended.

Assistance was provided to the principal investigator, Herbert G. Poertner, by James J. Anderson, Stifel W. Jens, John Reindl and Audrey E. Poertner. Richard H. Sullivan, Associate Director for Technical Services of the American Public Works Association, and the APWA Water Resources Committee provided assistance with surveys and report review. Many representatives of public agencies, engineering and law firms, land development firms and educational institutions provided information and guidance.

REFERENCES

1. Practices in Detention of Urban Stormwater Runoff, by Herbert G. Poertner (for the Office of Water Research and Technology, U.S. Department of the Interior); published by the American Public Works Association, June 1974, 231 p

2. The Beneficial Use of Stormwater, by Hittman Associates, Inc., for the U.S. Environmental Protection Agency, Washington, D.C., January 1973, 266 p, (reference pp 65-97)

3. Development of a Flood and Pollution Control Plan for the Chicagoland Area, Summary of Technical Reports, by the Flood Control Coordinating Committee, Metropolitan Sanitary District of Greater Chicago, Chicago, Illinois, August 1972, 111 p

4. The San Francisco Master Plan for Stormwater Management, City and County of San Francisco, San Francisco, California, 1972

5. Improvements to the Boston Main Drainage System, (Vols. I, II), Camp, Dresser & McKee, Inc., Boston, Massachusetts, September 1967

6. Reduction of Hydraulic Sewer Loading by Downspout Removal, G. L. Peters and A. P. Troemper, Journal of the Water Pollution Control Federation, January 1969

QUESTIONS AND ANSWERS

(Following Herbert Poertner's paper, "Stormwater Detention and Flow Attenuation")

Comment(Whitey Secor): In a stormwater detention program, I think it is necessary to examine where you are located in the watershed. If you are downstream, you must be careful so that you don't compound flooding with released flows from upstream detention facilities.

Question(Whitey Secor): Using detention facilities, or drop structures in stream channels, you are either reducing the velocity or increasing the duration of the flow--resulting in a longer time for bank-full conditions downstream. Have you evaluated the net effect of channel-bank erosion for that situation versus an uncontrolled situation? There appears to be some conflicting data on this. One source says that you let the peak flow come and you get out-of-bank flow which constitutes less erosion potential on the stream banks. Other people say that the increased flow duration causes greater bank erosion.

Poertner: I haven't made such a study; and, I can see that such an investigation would require a great deal of field study. Does anyone here have any information on such studies?

Comment: I am on an Interagency Personnel Assignment from the U.S. Soil Conservation Service. We have tried to evaluate this for Northern Virginia; but, we have not been able to come up with an answer.

Question: You mentioned, in flow attenuation, about having steep slopes and vegetation cover before the runoff is discharged into a drainage ditch or stream. I am especially interested in runoff in developed areas where there is erosion. Are there any published works that indicate the degree of removal, and what effect that has on water quality--by having sheet flows directed across a vegetated buffer, located parallel to a stream?

Poertner: I don't know of any such information being available. However, I believe that the method you described offers a good opportunity for reducing velocities of runoff and collecting eroded soils. This should reduce the amount of pollutants that ordinarily enter a stream with eroded materials. This technique could constitute a beneficial effect in preserving the water quality of the receiving stream.

III. Institutional/Legal Issues of Urban Stormwater Management

URBAN STORMWATER MANAGEMENT
PROBLEMS AND SOLUTIONS

Overview of a Nationwide Study

by

Herbert G. Poertner
Engineering and Research Consultant
Bolingbrook, Illinois

INTRODUCTION

I am presently engaged in a field study* of institutional problems, solutions and impacts of urban and metropolitan stormwater management. The purpose of the study is to identify and analyze various typical problems that prevent or delay the development of effective and economical stormwater management programs. Solutions to these problems that have been used, or proposed, in various places are being investigated to see whether they have transferability for solving problems in other locations. The positive and negative impacts of ongoing stormwater management programs are being evaluated to the extent possible.

Stormwater management, as viewed in this study, encompasses both "control" activities and "developmental" activities. The control activities are principally those relating to regulating local flooding, pollution, erosion and siltation; whereas, the developmental activities relate to providing and enhancing social values, such as recreation and public health, and improving the ecology, physical environment and aesthetics of local areas.

---

* The study is financed in part by the United States Department of the Interior under the Water Resources Research Act of 1964, Public Law 88-379, as amended. A draft of the final report is now being prepared.

Institutional problems being investigated are those that arise in creating, supporting and operating local stormwater management organizations as well as problems associated with technical activities such as planning, engineering, constructing, operating and maintaining physical facilities. All of the above problems, as a group, can be characterized generally as legislative, legal, organizational, administrative, political, jurisdictional, social, environmental, ecological, economic, financial, scientific and technical. Of special interest are those problems which develop when the stormwater management arm of a local government or public agency interacts with the private sector (land developers), other local public agencies, and various state and federal agencies. Included in this group are problems of overlapping jurisdiction and authority, non-uniform policies and regulations within a metropolitan area, disputes concerning the intent of duly enacted legislation, problems in joint-financing of stormwater management facilities and programs, and others.

In the process of investigating the institutional management problems of these local organizations, efforts are being made to identify, analyze and evaluate the "impacts" that are attributable to the implementation and operation of stormwater management programs and facilities. These impacts may be positive or negative and, generally, they can be considered as the secondary effects that are imposed upon people and/or nature by virtue of the primary activities of the management organization. They can be classified in four major groups: social, economic, political and physical (environmental and ecological).

The study methodology is founded upon conducting personal interviews in selected urban and metropolitan areas across the United States. Detailed case studies are being made in the metropolitan areas of Denver and Chicago and in Fairfax County, Virginia. Included in the groups of persons being interviewed are elected officials, appointed officials and staff personnel of local and state governments and other public agencies, staff personnel of federal agencies, planners, engineers, land developers, lawyers, educators and civic leaders.

OVERVIEW OF FINDINGS

Priorities and Attitudes

After conducting interviews for the study, it became evident that many areas of the United States have similar problems relating to stormwater management. The professional staff in most municipalities now give stormwater management a much higher priority, --primarily because of the many flooding problems and the increase in damages and inconvenience occurring in recent years. Most elected officials are becoming more concerned about these problems and are giving higher priority to the control of stormwater flooding and water pollution. However, some officials are more interested in and responsive to broad, social-type projects that can be seen, used and appreciated by the voters on a regular basis, rather than stormwater projects which often directly impact only a small percentage of the voters. Unfortunately, most citizens give stormwater a low priority unless they are affected directly.

Master Plans for Stormwater Management

Very few areas have a Master Stormwater Management Plan. Most of the persons interviewed feel that a plan is needed; however, many feel it would not be a wise use of available time and funds unless it can be seen that funds are obtainable for implementing the plan. Others thought a master plan is necessary now, even though implementation funds aren't available, so that priorities, alternative solutions, anticipated benefits and cost estimates can be developed. This information could then be used to inform and educate the citizens concerning stormwater management needs and develop long-range plans and schedules to solve these problems in the most cost-effective manner.

Financing

In all places visited during interviews, "money" was identified as either the greatest impediment, or a major problem, in establishing a timely and effective stormwater management program.

Few places in the country are satisfied with the financing methods they are now using for stormwater management. Many remarked that adequate legislation is needed to authorize the creation of Drainage Districts, on a watershed basis, without a vote of the citizens. It is felt that this should be a political problem and that action should be taken by the elected public officials, after conducting public hearings of affected citizens. Also, a legal basis is needed to assess charges against property in a more realistic manner according to benefits received. This requires new definitions of what constitutes "benefits". Most persons thought this would be an important step in solving the financing impediments to correction of historic stormwater problems in many areas.

Also, many of those interviewed thought a way should be found to fund construction of stormwater drainage facilities of sufficient flow capacity to meet future needs of an area when fully developed. It was thought that it was unfair for the developer and, ultimately, the new home buyer, to pay for the needed oversizing required to serve future upstream developments. Some persons thought this additional cost should be financed by the municipality and collected later when the upstream area is developed.

Most agreed that a service charge, or user charge, of some type, is necessary to finance effective stormwater management programs. However, most also thought it would be difficult to obtain voter approval of a service charge or user charge. In most areas, legislation would be required to authorize a charge of this type without voter approval. Many thought this should be a political decision and should be made, if needed, even if it was politically unpopular. It was felt that hearings should be held and the citizens fully informed so that they become aware of the need for a service or user charge. Some areas are now collecting a service charge for stormwater management, and some problems are being encountered in citizen protests and refusal to pay.

Many persons interviewed remarked that an urban stormwater system should be considered a "public utility" as are systems for sanitary waste collection and disposal, water supply, electricity, gas and telephone. Development of a utility operation for stormwater management would make "revenue bond financing" of facilities and programs feasible. This should permit obtaining capital and operating funds at lower interest rates than those inherent in other financing methods. Also, tap-in or development fees could be charged. This would make it possible to install needed facilities to serve future development.

In some areas, stormwater drainage facilities are being improved in low income and blighted areas using federal revenue sharing funds or community development funds. The objective is to upgrade the area and, hopefully, increase the tax base at a future date.

Cost-sharing is being used in many areas to finance improvements needed to correct existing stormwater-related problems. In most places where such financing programs are used, the property owners pay for the necessary materials and the municipalities provide the planning, engineering and field labor.

Citizen Education and Responsibility

Many persons stated that citizens must be educated to accept responsibility, including "financial" responsibility, for the operation of the stormwater management system. Even though they may not have any direct problems, it was felt that the citizen should understand that stormwater does flow into the drainage system from their yards, roofs, driveways, patios and sidewalks. Further, they should develop an understanding of how each piece of real estate contributes to the problems of flooding, pollution, erosion and siltation. An analogous situation exists in respect to some other public services. For example, all real property owners must pay for police and fire protection, yet most persons use these services only occasionally.

Very few areas have a good public information or community relations program. Those that do have found it helpful in making the citizens aware of the municipality's needs and in obtaining their support, especially for improvement bond programs. The citizens must be given the facts, many remarked; then most of them will support proposed programs. Many improvement bond programs have failed in the past because of poor public relations. Public officials often hesitate to attempt these programs now because of past failures; however, many persons expressed the opinion that worthy programs should be proposed again. They should be fully publicized and the citizens should be truthfully informed of the needs and costs. Too often the officials are afraid of public reaction and do not put forth their fullest, sincere efforts. Actually, very little could ever be accomplished in municipal government without the support of the citizens.

In some municipalities, neighborhood organizations have been formed and regular meetings are held. These meetings provide a forum for the municipal staff to present the needs of the municipality and an opportunity for the citizen to be heard. Many helpful and useful ideas have come out of these meetings.

In one city interviewed, a "city calendar" is published each year. This calendar is usable all year and keeps the citizens informed concerning community goals, needs, the previous year's accomplishments and plans for the current year. It contains much useful information.

Damages and Impacts

None of the cities or counties were found to have an effective method or system of determining the costs of stormwater damages and inconvenience to the citizens. Many of the events producing damages may recur several times annually and may interfere with commercial and industrial activities as well as the various emergency services provided in urban areas. Citizens are often delayed or unable to reach work because of flooding of streets and underpasses. The pollution produced by sewer overflows and backups together with the degradation of receiving water bodies are serious impacts as are soil losses and silt accumulations from uncontrolled erosion. Recurring stormwater flooding can have a serious impact on the overall economy of urban areas and reduce the market value of real property.

All of these physical problems produce economic losses in the communities impacted, and sometimes in areas outside those directly impacted. It is important to develop methods and on-going programs for assessing annual damages so that the figures can be used to compare the costs of needed improvements to the average costs of recurring damages. This information could be very useful to inform and educate the citizens about the true cost of delaying needed stormwater management programs and facilities.

Maintenance

Very few areas have a planned, systematic maintenance program for stormwater handling facilities. Maintenance is poor-to-fair in most areas, mostly due to the lack of programmed operating funds.

Also, the lack of right-of-way or easements along the streams and ditches compound maintenance problems in many municipalities. Most municipalities now require easements along the flow ways in new land developments, even in instances where there may be no public responsibility for maintenance. The difficult problem is to obtain these easements in previously developed areas. Many property owners prefer that the streams remain in their natural states without disturbances of the banks, vegetation, trees, brush, etc. They are reluctant to grant easements to the municipality for stormwater facility maintenance.

In most areas, maintenance crews have other responsibilities and perform stormwater maintenance only when problems occur. In some areas, the sanitary sewer department crews and equipment are used to maintain stormwater drainage facilities. Efforts are made to record the costs separately so that revenue from sanitary system service charges is not used for stormwater system maintenance.

Public officials in most areas would like to upgrade their maintenance programs. This would help solve many of their stormwater problems.

Ordinances and Regulations

Most urban places have adopted ordinances and regulations for stormwater management, including flood plain management, in recent years. However, many of these ordinances are not fully effective and amendments are planned in many areas. The ordinances often are not written clearly and problems of interpretation have developed, even within the department of the public agency that is responsible for enforcing the regulations. As a result, plat approval is delayed. This creates serious problems for the land developers.

Land developers in most places are cooperative, even though they do not like many of the new stormwater management regulations. They believe many of these regulations are too stringent and that the regulations are producing an adverse economic effect on the housing market. Developers are accepting these regulations as long as they know what the regulations are and know that all developers must observe them uniformly.

Many public officials believe that the local ordinances and regulations should be realistic and conducive to flexibility of approach in land development. Too often a "cook-book" approach and solution is required irrespective of the circumstances.

Regional Management

In past years, in most urban places, there has been little cooperation and coordination between neighboring jurisdictions. Today, because of the many problems that affect adjoining municipalities, more consideration is being given to each others problems. Some areas now have joint planning commissions which have reduced inter-jurisdictional problems, particularly in new development.

Many believe that some type of regional form of stormwater management is needed, partly because watersheds reach into several political jurisdiction in many urban areas. Also, many believe regional planning and design criteria should be established and that uniform regulations for stormwater drainage and control of flooding, pollution, erosion and siltation are needed. Suggestions were made for regional offices of federal agencies to establish planning offices in larger urban areas to oversee and review plans that affect more than one jurisdiction.

It was suggested that some type of regional inspection agency would be helpful. This would make it feasible, financially, to hire well-qualified hydrologists and engineers to inspect stormwater drainage facilities over entire watersheds. The costs could be shared by all the jurisdictions involved according to use. Political interference could be minimized or eliminated.

Providing inspection and enforcing regulations during and after land development activities is a problem in many areas because of an inadequate staff of qualified engineers and technicians. This is particularly a problem in places having an erosion and sediment control ordinance to regulate grading and excavation at new land developments.

Interagency Relationships

Inter-department and inter-government communication is a problem in some places. Actually, many stormwater management problems sometimes are compounded because of insufficient coordination and cooperation, and because too many local departments and agencies are involved in establishing and administering regulations.

A problem in some places is the poor cooperation between the state highway department and the municipalities. Some state highways are built with undersized bridges, culverts and drainage facilities because they sometimes use less stringent design criteria than those adopted and used by the local governments. Also, stormwater runoff is often discharged into the local drainage system which may not have been designed to handle the added flows. Corrective measures often cause local disruption of streets and private property and may require unscheduled expenditures by the local governments for structural solutions.

Many municipalities are purchasing land in the flood plain so that land development in flood prone areas can be controlled. Most of this land is being developed for parks, recreation, wildlife and forest preserves, bike trails, groundwater recharge, and other public purposes. For a successful land acquisition program, cooperation is needed from all local governments in which a given flood plain lies. Many of these municipalities are hoping for federal or state financial aid so that more flood plain property can be purchased.

Several persons stated that combining stormwater management projects with other public projects and activities has been very helpful in obtaining public support. This is particularly true for parks and recreation projects. Such multiple-purpose projects require a high degree of cooperation and coordination between departments and between cities and counties. Sometimes, state enabling legislation may be needed to permit implementation of multiple-purpose projects when more than one unit of government is involved.

Many municipalities have serious problems with excessive infiltration of groundwater into sanitary and combined sewers through defective pipe joints, ruptured pipes or manholes. Inflow of surface runoff through manhole openings and joints into sanitary sewers also occurs. This often produces sewage back-ups into basements and other habitable areas will often occur during wet weather--causing health and safety hazards, property damages and economic losses. Sometimes these problems develop outside the areas where the infiltration or inflow contributions are greatest. Also, treatment plants are often by-passed during periods of high sewer flow rates and the resulting overflows and discharges produce serious pollution of the receiving water bodies, beaches and adjacent lands. Many streams, ponds and lakes are now "dead", and some cause serious odor and health problems. In a metropolitan area where infiltration is significant and wastewater is collected from many separate political jurisdictions for central treatment, a coordinated and cooperative approach by all juristions involved is necessary to reduce the pollution and flooding impacts from sewer system surcharging.

In some areas, "piece-meal" solutions have been attempted to solve stormwater problems, such as channel improvements in the middle of a watershed. As a result, the flooding problem is often transferred or compounded in downstream areas. Most persons agreed that channel improvements should begin at the mouth of the stream to be fully effective. Again, this requires coordination and cooperation between all of the local governments involved and, usually, the state regulatory agency.

Many of those persons interviewed would like to see the state and federal governments become more involved in stormwater management. They feel state stormwater programs should be developed and guidelines established. Also, many persons feel the federal and state governments should develop financing programs to provide financial assistance for making needed capital improvements before, instead of after, problems and damages occur.

Many persons said that the federal government should reduce the time needed to implement a federally-funded project after it is approved. Sometimes 8 to 10 years elapse from the time a project is approved until construction is started. In the meantime, damages and inconvenience continue and land and construction costs increase. Many are of the opinion that the federal government is not giving enough consideration and resources to the stormwater problems that are occurring all over the nation today.

Flood Plain Maps

In many places, hydrologic maps delineating the 100-year flood plain are not accurate, and local officials consider this a serious problem. It is particularly bothersome in areas where minimum elevations must be established for construction. Many urban places are now having the flood plains of local streams delineated by the U.S. Army Corps of Engineers or the U.S. Geological Survey. It is felt that these maps should be updated at regular intervals. A great deal of preliminary flood plain mapping has been done under the National Flood Insurance Program; however, a great deal more remains to be done. No doubt, many years will be required to develop all the flood plain maps needed in urban communities.

Engineering Design and Responsibility

Most urban communities are giving serious consideration to the use of stormwater detention facilities for runoff control to reduce peak flow rates into drainage systems. Because many storm sewers and combined sewers in older urban areas have insufficient flow and storage capacity, detention in the upstream areas appears to be the most practical means available for solving this problem. In many places, detention is being used and has been found satisfactory and money-saving; however, land developers often resist such new concepts.

Some public officials expressed the opinion that the engineering design of all stormwater facilities, together with careful construction inspection, should be provided by the local municipality. This should assure the provision of satisfactory facilities. By assuming this responsibility, the dedication and acceptance of the completed facilities would be expedited--benefitting both the land developer and the municipality.

CONCLUDING REMARKS

Although many of the institutional problems and alternative solutions pertaining to stormwater management were identified in this paper, there are many others of importance that were not addressed, or discussed only briefly. These include: development of management policy, goals and objectives; fragmented authority; extent of responsibility and jurisdiction; organization and administration; planning, to decrease the implementation time lag; problems in developing and adopting needed legislation and administrative regulations; application of non-structural solutions for preventing problems; legal matters and laws pertaining to stormwater management; politics; relationships between land developers and public agency officials; problems with property owners; development of better public works programs in street cleaning, refuse disposal, etc. to minimize pollution of runoff and impacts on water quality; and education of the public to understand better the possible consequences of stormwater mismanagement.

THE INTERGOVERNMENTAL TANGLE FACING STORMWATER CONTROL

by

Andrew B. Waldo

Rapid urban growth in this country has indelibly marked our lives with problems, which are by nature increasingly complex. The environmental threat posed by stormwater runoff is among these many problems generated in the wake of development. Where such pollution endangers the quality of receiving waters, it respects no political boundary. As a result, intergovernmental cooperation becomes a necessity in order to carry out technical solutions effectively; yet when local government is called upon to meet this need, it appears ill-equipped to supply areawide answers to those matters best handled at that level. A stormwater program must therefore address not only technical solutions, but must also consider the means by which local government will cooperate to implement them.

In the past, it was thought that the overriding purpose of a stormwater drainage system should be fast removal and efficient disposal. The management of these systems was seen as an engineering problem divorced from other urban systems and activities. In addition, sewer design by the rational method considered neither the timing of the flow nor the quality of the flow. As a result, those designs employing detention and storage were, for the most part, arbitrarily eliminated. Although the environmental damage caused by stormwater runoff is now recognized, a hold-over from this past remains--the view of stormwater control as a local problem with an engineering solution. Consequently, our sewer systems are incapable of maintaining the quality of our streams. Were the damage born only by those who failed to plan effectively, the matter would lose some of its urgency. Unfortunately, the effects of stormwater runoff are cumulative. The neglect of one community is paid for by another. Such being the case, piecemeal solutions become inadequate. Effective intergovernmental coordination is thus needed for reasons of equity as well as for reasons of hydrology.

Past failures, however, do not constitute a sufficient reason for intergovernmental coordination. Each community differs in the degree to which it suffers from the ill effects of stormwater runoff and some areas may not have a serious problem whatsoever. In this light, the characterization of the specific problem becomes all too important. Data must be collected and analyzed. Coordination among local governments is then needed where common problems are apparent, but it will only occur, most probably, where these common problems have been demonstrated clearly.

For the present, a major obstacle to coherent administration is the fragmentation of responsible levels of government. As a case in point, the stormwater programs of two neighboring counties in Maryland--Prince Georges and Montgomery Counties--may be contrasted. Both counties share the same history. Until 1968, the Washington Suburban Sanitary Commission was responsible for stormwater management in both areas. After that time, Montgomery County took over this duty from the Commission; Prince Georges did not.

As the cornerstone to its efforts, Prince Georges County has created a Stormwater Management Technical Review Committee which answers to the county planning board. This group represents the Park and Planning Commission, the Soil Conservation District, the Washington Suburban Sanitary Commission, and the Department of Public Works. There are thus four agencies responsible to a planning board. Each of the four agencies has a different responsibility and a different interest.

To begin with, the Park and Planning Commission has the obligation to recommend the installation of detention facilities where they feel necessary. In turn, the Soil Conservation District evaluates the construction specifiactions of the detention plan. Then, because the Sanitary Commission must inspect and maintain the facility on completion, they have review authority as well. Finally, the Department of Public Works has a say since their concern involves a related issue--the public streets. All of these agencies advise the County Planning Board which under its independent powers has the final authority.

Many of those involved with the stormwater program in Prince Georges County agree that their policy is ad hoc and haphazard. Most of all, their procedure is highly fragmented. Each agency has a different interest, but all have a say in the matter; conflicting voices result. For instance, the Sanitary Commission does not favor a blanket requirement on developers for stormwater management. The Park and Planning Commission, on the other hand, is in favor of such a constraint. For its part, the County believes it has inadequate funding for inspection and maintenance of facilities once completed.

In contrast, Prince Georges' neighbor, Montgomery County, has centralized its stormwater management program within the Montgomery Soil Conservation District pursuant to the Maryland Sediment Control Act of 1970 and to a 1971 opinion of the Maryland Attorney General affirming the requirement of stormwater management measures under the intent of the Maryland Sediment Control Law. Montgomery County's stormwater control policy, along with some recent alterations, has thus been in effect since 1971. Within this framework, Montgomery County has developed a far-sighted program. Although the comparison of the two counties simplifies a number of highly complex factors, it serves to indicate the divergence of these adjoining counties in their approach to stormwater management. The fragmentation of responsiblity may well impede the success of a program.

From this perspective,the pattern of organization will be important to the attainment of perceived goals.

> Some values are served by one pattern of organization, while other values are brought to the fore by a different pattern. The rational way to proceed, therefore, is to try to sift out the major values or goals to be sought, and to determine the relationship of different patterns of organization as a means to the attainment of these goals. If a relationship of means to goals can be objectively established, then the task becomes one of determining in any given local gommunity which values are to have priority. Once this step has been accomplished, decisions as to location and organizational form of the planning function can be made.[1]

Characterization of the problem, again, is critical to understanding the most effective means of administration. In an absolute sense, the ultimate criterion for a given organizational scheme to control stormwater runoff lies in the measured benefits to water quality. Such a criterion, however, remains difficult to measure in practice.

Nevertheless, the haphazard results in Prince Georges County may, in part, be traced to the pattern of organization taken. The planning board submits to the review committee only those plans which the Board feels have an inadequate consideration of the impact from runoff. If a planning board is to gain from the technical experience of the agencies which advise it, all development plans should be review by them. Some of the difficulties facing this county thus appear the partial result of their institutional arrangements.

While Montgomey County has centralized its program within a soil conservation district, such special purpose districts do not offer a general solution to the fundamental dilemma at hand. An instance of an acute jurisdictional morass existed in one county which included within its borders one county-wide drain board, one county-wide park board, three separate water management districts, two soil conservation districts and most of one irrigation district. To make matters even worse, that irrigation district extended into two other counties so that coordination between the several districts would require contact with two drain boards, three park boards, four water management districts, and four soil conservation districts. This chaos is not atypical. One survey indicated that there were 143 counties actoss the nation which contained over 25 special districts within their boundaries.

As an intergovernmental solution, special districts have several failings. First, there is commonly a duplication of roles to be fulfilled by different districts. Second, there does not often exist a mechanism for statewide supervision that would ensure adequate coordination of the districts' plural and separate efforts to meet their overlapping responsibilities. Finally, the variations possible in jurisdictional boundaries make cooperation even more difficult.

Given the dimensions of the intergovernmental problem and in light of the variability inherent in the impact of stormwater runoff, no one all-encompassing institutional solution will be found. These are the realities to be faced due to the myriad patterns of government within our federal system. We confront a balkanized arrangement of functions with little hope of strong regional structures forthcoming.

For their part, theorists have pointed to many better ways of governing ourselves in the face of regional problems. Federation, consolidation, and intergovernmental service agreements are some of the most commonly mentioned. Structural answers have been regional councils, regional special districts, and metropolitan counties to name a few. Theory offers little solace, however, because theorists fundamentally disagree. An important point remains: We cannot wait for radical reorganization of the political structure. Since 1945, for example, only seven city-county consolidation referenda have been approved in areas with a population over 100,000.

Because structural revision appears an unlikely development in the forseeable future, the means available to abate the pollution caused by stormwater runoff are constrained to those which are nonstructural. As for the technical solutions, estimates for treatment of stormwater discharges, for example, have proposed astronomical costs. Precluding structural measures as a feasible alternative, nonstructural ones appear attractive. In a similar way, because radical political reorganization around the watershed will, most probably, not occur, local government must look to informal mechanisms and existing institutions. Both technically and administratively, then, stormwater management programs are severely limited by the practical alternatives available.

Intergovernmental cooperation may be reached, however, in some instances without structural change. To control sediment runoff from construction sites, local governments can simultaneously adopt ordinances which set performance standards for the developer. In Georgia, Dekalb County passed such a law requiring stormwater management. As a result, Dekalb's neighbors followed suit and now, Clayton and Gwinett counties have similar regulations. Another adjacent county, Fulton, has not passed a specific ordinance of this type yet it achieves the same effect through an informal policy carried out by the Department of Planning. Fulton is at the point of passing a law of this kind, which would make stormwater managment a requirement in a total of four neighboring counties.

These counties evidence a common problem: they share the same drainage areas, have similar soil types, and in all, have identical stormwater management needs. This example suggests that structural change through formal mechanisms may not be a necessary condition to the success of an areawide approach to stormwater management.

Given the depth of the problem, the ultimate question still remains: what minimal level of intergovernmental cooperation is necessary and what form must it take in order for an effective stormwater management program to be carried out? While the answer to so universal a question defies a general anaylsis, the first step must begin with a characterization of the problem. This effort may vary from a simple qualitative estimation to a highly complex time dependent analysis. It may, depending on the resources available, either look for critical areas of impact by a crude evaluation of related variables which affect the pollutant loading or enter into a sophisticated modeling process of water quality response. Since a discussion of the methods available to determine the extent and degree of water quality damage is considered elsewhere in this conference, let us then suppose that at least a coarse notion of the problem has already been obtained. At this juncture, the area faces the difficult task of defining an adequate program of control measures.

Best Management Practices have been proposed as one means of controlling the pollution caused by runoff. As a simple example of how these BMP's might work in practice, let us assume that several adjoining communities lie in the same drainage agrea, and have similar runoff coefficients, soil types, and rainfall. Four control measures may be considered: street sweeping, erosion control practices, detention tanks, and catch basin cleaning.

From an analysis of population and traffic densities as well as land use, zones of highest street loading intensities may be developed for a range of pollutants after a sampling program is completed. Again, the assumption here is that other data concerning soil types, rainfall-runoff relationships and slopes, for example, have already been inspected. Next, areas of high earth disturbance can be located. For construction sites, this effort may entail a collection of building permits. Furthermore, depending on the drainage characteristics of the community and from the earlier evaluation of receiving water impacts, a detention tank might be designed. If the density of catch basin placement is known, estimates of load reductions can follow which form a first notion of the cleaning program to be undertaken. Such, then, are the rudimentary steps toward a formulation of a BMP, albeit greatly simplified.

In this example, the communities have been disaggregated into zones where the four techniques in question might be applied. Essentially, these zones constitute areas which contribute highly to the pollutant loading of the stormwater runoff; this example has generated areas of high street loading intensities and those of high earth disturbance. In addition, potential areas which might be served by a detention tank have been defined as well as the densities of catchment basins. Once this process of definition has taken place, an analysis may begin to determine the most effective, least costly, application of the techniques and the resultant enhancement of the receiving waters. Having identified debris laden streets does not, however, mean that the most efficient use of the street sweeper is to automatically cover them.

Interdependence of pollutant sources and of technique application becomes a critical factor. If, for instance, a construction site lies next to a roadway and it does not have erosion control structures on it, then an enormous loading of total solids would be measured on the roadway, thus making that section of street an area of highest pollutant intensity. Sweeping that avenue may not be the answer. Rather, the solution would more likely be the implementation of an erosion control plan on the construction site. The point is simply that a technique to control stormwater runoff cannot be applied arbitrarily and without consideration for the interdependence with other techniques and other pollutant sources. Put another way, a catch basin cleaning program could not be designed independent of a street sweeping program for the sweepers will reduce the collected solids in the catch basin. A best management scheme must therefore take into account the totality of the system.

A Best Management Practice can be determined though which applies these techniques with an appropriate concern for this interdependent effect. Other factors can also affect the program such as the lack of off-site parking or the inability to alter the no parking ordinance to suit the street sweeping routes. In addition, it may be impossible for political reasons to require the stormwater control practices from the developer. The point remains, however, that a planning process, taking into account the related variables and factors at one degree of sophistication or another, can design a Best Management Practice to control the impact of stormwater. This process will result in alternative programs in light of the beneficial use intended for the receiving water.

The fundamental question asked earlier can now be addressed: what form should the intergovernmental cooperation take? The answer will depend upon the areas identified as having a significant impact on the receiving water as well as upon the best management practices generated in the planning process. Let us assume that the communities in this example directly adjoin and that the transportation network covers them evenly. In this case, if it is determined that an area of multiple jurisdictions would benefit from street sweeping, then an interlocal contractual agreement may be called for which shares the capital investment in sweeping equipment and the maintenance costs for its operation. On the other hand, if an area of growth straddles jurisdictions, then the simultaneous adoption by ordinance of performance standards for developers may be a needed measure. Clearly, no one intergovernmental measure applies to every case. Each community must tailor its Best Management Practices and its intergovernmental needs to the specific problems it faces and to the problems shared with other communities in the area.

The implementation of an effective stormwater management program will hinge upon a characterization of the problem. Even if this is accomplished, however, there will be difficulties of administration for the community that may be internal or external. Fragmentation of responsibility will undoubtedly arise within many local government organizations and political impediments will obstruct cooperative efforts. In addition, technical problems will surround the design of the Best Management Practice. Nevertheless, some hope remains. The concept of BMP within a planning process offers the possibility of identifying the ill effects of stormwater, developing alternative strategies to control it, and finally, clarifying the common needs of an area.

Even if the commitment to water quality is strong, intergovernmental conflicts may block the best of intentions. But we must begin at some point. A first requirement is public awareness and participation. Only after a recognition occurs of the environmental threat posed by runoff will there be a willingness to face intergovernmental solutions. To this end, public participation becomes a necessity. Citizen awareness will instill an incentive for local leaders and representatives to seek cooperation. An example of an effective program of public participation is the one carried on by the Huron River Watershed Council in Michigan. Through public service annoucements, public meetings, and disseminated information, the Council has had wide response from the public-at-large. In particular, the public service announcement proved an inexpensive yet effective method to gain citizen support for the Council's activities. Whatever the method chosen, stormwater management must be accompanied by public awareness.

In summary, the overarching consideration in a stormwater management scheme is the quality of the receiving waters and the developed plan must tailor itself to the beneficial uses intended for these waters. To protect these uses stormwater runoff must be seen not as a local problem, but rather as a dilemma of areawide and regional proportions. The approach taken cannot rely on isolated engineering efforts to solve it, but must, instead, view the urban system as a totality. Toward this end, a characterization of the specific dimensions of the environmental damage caused by stormwater becomes critical. Out of this effort needs are clarified. Once these needs are understood the intergovernmental mechanisms available can be brought to bear upon the problem. Intergovernmental cooperation, however, hangs on the clarity of the demonstrated needs. As a result, the pattern of organization can suit the goals desired. It is suggested here in a very simplified way that an effective measure of control can result if local government approaches the problem in an integrated manner. Surely, these problems are complex and the institutions cumbersome, but the rudiments of an answer are present.

NOTES

1. *Local Planning Administration* (Chicago: International City Managers' Association, 3rd ed., 1959), p. 40.

INTERGOVERNMENTAL RELATIONSHIPS IN THE CONTROL OF STORMWATER RUNOFF

A SELECTED BIBLIOGRAPHY

The following bibliography is designed to provide references, both general and specific, toward a better understanding of the intergovernmental relationships which must be addressed in any program directed to the management of stormwater runoff. Stormwater runoff, as a problem of local governments, clearly is linked to other services provided by local areas such as sewerage and drainage. For this, reason, general references are provided.

GENERAL

Advisory Commission on Intergovernmental Relations. *The Challenge of Local Government Organization; Substate Regionalism and the Federal System*, v. 3. Washington: U.S. Government Printing Office, 1974.

Advisory Commission on Intergovernmental Relations. *A Handbook for Interlocal Agreements and Contracts*, Report M-29. Washington: U.S. Government Printing Office, 1967.

Advisory Commission on Intergovernmental Relations. *Intergovernmental Responsibilities for Water Supply and Sewage Disposal in Metropolitan Areas*, Report A-13. Washington: U.S. Government Printing Office, 1962.

Advisory Commission on Intergovernmental Relations. *The Problem of Special Districts in American Government*, Report A-22 Washington: U.S. Government Printing Office, 1964.

Antieau, Chester James. *Antieau's Local Government Law: Independent Local Government Entities*. New York: Matthew Bender, 1970. v. 3a.

Beck, R.E. "The Law of Drainage." *Water and Water Rights.* Indianapolis: Allen Smith Co., 1972, v. 5, secs. 450-59, pp. 475-648.

Carrell, Jeptha J. "Learning to Work Together." *National Municipal Review.* v. 43, no. 10 (November 1954), pp. 526-533.

Environments for Tomorrow, Inc. McLean Va. *Management of Water Resources for Urban Environmental Assessment*. Washington: Office of Water Research and Technology, 1974. NTIS PB 239-301.

Foster, William S. "Metropolitan Sewerage Pacts in 1960." *American City*. Part I, "Inter-city Contracts," v. 75, no. 10 (October, 1960), pp. 87-89. Part II, "Intermunicipal Sewerage Compacts," v. 75, no. 11 (November, 1960), pp. 169-176. Part III, "Metropolitan Sewerage Compacts," v. 75, no. 12 (December 1960), pp. 143-147.

Graves, W. Brooke. *Interlocal Relations*: *The History and Background of Intergovernmental Agreements*. Information and Education Service Report No. 23. Washington, D.C.: National Association of Counties Research Foundation, 1963.

Grosenick, Leigh. "A Comparative Analysis of Joint Exercise of Powers Legislation in the United States." Unpublished M.A. Thesis, University of Minnesota. Minneapolis, 1965.

Hammill, Anne, and Hanson, Ivan. *Natural Resource Special Districts in Appalachia* ... *Review of Enabling Laws*. Washington, D.C.: Economic Research Service, Department of Agriculture, 1970.

Haskell, E.H. et al. *Managing the Environment: Case Studies of Nine States* . New York: Praeger, 1974.

Hillenbrand, Bernard. "Urban Counties in 1958". *Municipal Yearbook, 1959*, pp. 60-66. Chicago, Ill.: International City Manager's Association.

Hines, William and Smith, Jamison. *Rational Institutional Arrangements for Water Resources Management*. Ames, Iowa and Washington, D.C.: Iowa State Research Institute; Office of Water Resources Research, Department of the Interior, 1973. NTIS PB 234-627.

International City Manager's Association. *The Municipal Yearbook*. Annual. Chicago, Illinois.

International City Manager's Association. *City County Cooperation in Providing Municipal Services.* MIS Report No. 191, December 1959. Chicago, Illinois: 1959.

International City Manager's Association. *Contracting for Municipal Services*. MIS Report N. 240, January 1964. Chicago, Illinois: 1964.

Jarz, Emil F. "Intermunicipal Co-operation in Sewerage Disposal." *Public Management*. v. 24, n. 9 (September 1942), pp. 267-72, Krause, Norman P. Intergovernmental Relationships in the Administration of Water Resources, Water Resources Center Research Report No. 18. Urbana, Illinois: University of Illinois, September 1968.

Lauer, T.E. "District Control of Water Resources", University of Detroit Law Journal (October 1959), v. 37 n.1, pp. 28-75.

Maloney, Frank and Plager Sheldon. "Diffused Surface Waters--Scourge or Bounty", Natural Resources Journal (January 1968), v. 8 n.1, pp. 72-113.

Martin, Roscoe C. Metropolis in Transition: Local Government Adaptations to Changing Urban Needs. Washington, D.C.: Housing and Home Finance Agency, September 1963.

National Institute of Municipal Law Officers, NIMLO Municipal Law Review. Annual. Washington, D.C.

National Service to Regional Councils, A New Dimension in Local Government Regionalism: Intergovernmental Relations. Washington, D.C. 1971, NTIS PB 205-326.

Norton, G.A. and MacMillan, J.A. A Framework for Economic Planning of Watershed Drainage, Research Report No. 6. Winnepeg: Agassiz Center for Water Studies, Manitoba University, 1972.

Pock, Max. Independent Districts: A Solution to Metropolitan Area Problems. Ann Arbor: Legislative Research Center, University of Michigan Law School, 1962.

Poertner, Herbert. Practices in Detention of Urban Stormwater Runoff. Special Report No. 43. Chicago: American Public Works Association, 1974.

The Research Group, Inc. Comparative Analysis of Three Research Strategies Directed Toward Multi-Government Provision of Public Services. Richmond and Washington, D.C.: Division of State Planning and Community Affairs, Commonwealth of Virginia; Policy Development and Research, Department of Housing and Urban Development, 1973. NTIS PB 231-896.

Wendell and Schwan, Washington, D.C. Intergovernmental Relations in Water Resource Activities. Washington, D.C.: 1972. NTIS PB 210-358.

Wilkinson, Kenneth P. and Singh, R.N. Generalized Participation of Voluntary Leaders in Local Projects. State College, Mississippi: Water Resources Research Institute, Mississippi State University, 1969.

Yeutter, Clayton K. Water Administration...A Suggested Institutional Model, Department of Agricultural Economics Report No.46. Lincoln, Nebraska: University of Nebraska.

CASE STUDIES

California

Baruth and Yoder, Walnut Creek, California. Storm Drainage. NTIS PB 211-048.

Beebe, James W., and Firestone, Alan M. "How a Combination of Revenue Bond Financing and Joint Exercise of Powers Enables the San Diego Metropolitan Area to Solve Its Sewage Disposal Problem." Western City. Vol. 37, No. 4 (April 1962), pp. 27-28.

California. Legislature. Assembly Interim Committee on Municipal and County Government. Transcript of Proceedings on the Subject of Cooperative Metropolitan Services, November 13, 1962. (Mimeographed).

California. Legislature. Senate Fact Finding Committee on Local Government. Report to the Legislature, 1961 Regular Session. Sacramento, California: 1961.

Council on Intergovernmental Relations, Sacramento, California. San Anselmo Government Structure Study Tasks 1-4. Sacramento: 1972. NTIS PB 212-889.

Crouch, Winston W., and Maccoby, Wendell. Sanitation Administration in the Los Angeles Metropolitan Area--A Study in Development of Public Policy and Administrative Organization. Los Angeles, California: University of California, Bureau of Governmental Research, 1952.

Gove, Samuel K. The Lakewood Plan. Commission Papers of the Institute of Government and Public Affairs. Urbana, Illinois: University of Illinois, May 1961.

Jamison, Judith Norwell and Bigger, Richard. "Metropolitan Coordination in Los Angeles", Public Administration Review. Vol. 17, No. 3 (Summer 1957), pp. 164-169.

Kenny, James P. et al. North Richmond San Pablo Bay Area Study. Sacramento, California: Council on Intergovernmental Relations, 1971. NTIS PB 211-777.

Ketcham, Ronald M. "Intergovernmental Cooperation", Tax Digest. Vol. 19, No. 4 (April 1941), pp. 124-125 and 134-135.

League of California Cities. Inter-Municipal Cooperation Through Contractual Agreements. Berkeley, California, 1963. 48pp.

Warren, Robert O. Government in Metropolitan Regions: A Reappraisal of Fractionated Political Organization. Davis, California, 1966. 327pp.

Connecticut

Kasperson, Robert E. *Political Organization and the Planning of Water Resources Development in the Farmington Valley; a Preliminary Profile.* Storrs, Connecticut: Institute of Water Resources, University of Connecticut, October, 1967.

Delaware

Dolan, Paul. "Informal Approaches to Administration in Northern Delaware", *County Officer*. Vol. 23, No. 3 (March 1958), pp. 58-59,70.

"Sewage Problems Can Be Solved Without Separate Districts: Wilmington, Delaware", *American City*. Vol. 71, No. 2 (February 1956), pp. 138-139.

District of Columbia

Metropolitan District Study Commission. *Report on the Metropolitan District Commission and Government Functions Committee of the Capital Region Planning Agency*. Hartford: 1965.

Florida

Maloney, Frank. "Single Purpose and Multi-Purpose Water Management Districts" in *Water Law and Administration: the Florida Experience*. Gainesville, Florida: University of Florida Press, 1968.

Thomas, Robert D. *Intergovernmental Relations and Responses to Water Problems in Florida.* Gainesville, Florida: Water Resources Research Center, University of Florida, 1972. NTIS PB 219-582.

East Central Florida Regional Planning Council. *The Relationship of Water Quality to Land Use Around Lakes.* Winter Park, Florida: June 1973.

Georgia

Burgess, James V., Jr.; Posey, G. Harold; and Bell, George A., Jr. *A Study of Intergovernmental Cooperation in Georgia: Legal Basis.* Athens, Georgia: The Institute of Community and Area Development, The University of Georgia, 1963.

Georgia Municipal Association. "Intergovernmental Cooperation: A Review of Cooperation Between Cities and Counties with Consideration Given to Progress Being Made and Suggestions for Further Cooperation" Part III. Atlanta, Georgia: 1965. 33pp. (Mimeographed).

Kates, R.C. *Georgia Water Law (Administrative Structures of Water Use and Water Courses Regulations)*. Athens, Georgia: Institute of Government, University of Georgia, 1969.

Illinois

Mann, Fred, et al. "Water Use Regualtion and Related Functions of State and Local Bodies" in Water Use Law in Illinois. Urbana, Illinois and Washington, D.C.: Illinois University; Economic Research Service, 1964. pp. 143-191.

Northeastern Illinois Planning Commission. "Intergovernmental Contracts and Agreements in Northeastern Illinois: A Preliminary Survey, September 1963". Chicago, Illinois: 1963. 2pp. (Mimeographed).

Northeastern Illinois Planning Commission. Manual for Intercommunity Councils. Planning Aids No. 8, Chicago, Illinois: October 1964.

Indiana

Stoner, John E. Interlocal Governmental Cooperation, With Special Reference to Indiana. Bloomington, Indiana: Indiana University Department of Government, 1964. 74pp. (Processed).

Iowa

Burrows, Tom G. Statutory Authorizations for Intergovernmental Cooperation in Iowa. Iowa Municipal Information Service, No.3, July 1964. Iowa City, Iowa: Institute of Public Affairs, University of Iowa, 1964, 7pp.

Otte, Robert C. Economics of Watershed Planning. Ames, Iowa: State University Press, 1961. pp. 277-292.

"Surface Water Drainage in Iowa", Iowa Law Journal. V. 50, pp. 818-836. (Spring 1965)

Kentucky

Owsley, Roy H. "The Kentucky Interlocal Cooperation Act", Kentucky Law Journal. Vol. 51, No. 1 (Fall 1962), pp. 22-33.

Maryland

Vaughan, W.S., Jr., Blanchard, H.A. and Manor, Anne S. State-County Interagency Procedures for Imposing Environmental Quality Controls on Water Oriented Development Activities. Washington: Office of Water Resources Research, July, 1974. NTIS PB 236-299.

Massachusetts

Dowling, Edward T. Permissive Legislation for Municipalities in Massachusetts. Amherst, Massachusetts: Bureau of Government Research, University of Massachusetts, May 1959. 32 pp.

Goodwin, George, Jr. *Intermunicipal Relations in Massachusetts.* Amherst, Massachusetts: Bureau of Governmental Research, University of Massachusetts, December 1956.

Michigan

Citizens Research Council of Michigan. *Staff Papers on Governmental Organization for Metropolitan Southeast Michigan.* Detroit, Michigan: January 1965. 238pp. (Mimeographed).

Citizens Research Council of Michigan. *Research Brief on Legislation on Intergovernmental Cooperative Agreements*. Detroit, Michigan: February 1966. 31pp. (Processed).

Marando, Vincent L. "Inter-local Cooperation in a Metropolitan Area: Detroit", *Urban Affairs Quarterly*. Vol. 4, No. 2 (December 1968).

Minnesota

Haik, Raymond *et al*. *Aspects of Water Resources Law in Minnesota.* Bulletin Minnesota University Water Resources Research Center, (June 1969).

Proceedings of Conference on Water Resources Problems and Research Needs in Northwestern Minnesota. St. Paul and Washington, D.C.: Minnesota University, Water Resources Research Center, Office of Water Research and Technology; Bemidji State College, Center for Environmental Studies, 1973. NTIS PB 237-503.

Mississippi

Jones, Arthur R., and McLeskey, Howard M. *Water Politics in Mississippi: A Comparative Analysis of Two Water Resource Development Organizations*. State College, Mississippi: Water Resources Research Institute, Mississippi State University, 1969.

Missouri

Davis, Lawrence O. "The Law of Surface Water in Missouri", *Missouri Law Review*. Vol. 24, No. 3, pp. 283-289.

The Governmental Research Institute. *Services Provided to Municipalities by the St. Louis County Government*. St. Louis, Missouri: April 1964. 11 pp. (Mimeographed).

Office of the St. Louis County Supervisor. *Services Available to Municipalities Through the St. Louis County Government*. St. Louis, Missouri. 32 pp. (Mimeographed).

Nebraska

Nebraska Soil and Water Conservation. Modernization of Resource District Legislation. State Water Plan Publication No. 402, March 1969.

New Jersey

Burch, Phillip H., Jr. Water Pollution Control in New Jersey. New Brunswick and Washington, D.C.: Bureau of Government Research, Rutgers, The State Univeristy; Office of Water Research and Technology.

Bureau of Government Research. Surface Water Control in New Jersey, Part II: Drainage, Flood Control and Related Policies in an Urban State. New Brunswick: Rutgers, The State University, August 1967.

Trafford, John E. "Intermunicipal Activities and Joint Services in New Jersey", New Jersey Municipalities. June 1965, pp. 8-11.

New Mexico

Clark, Ira G. Administration of Water Resources in New Mexico. Las, Cruces, New Mexico: Water Resources Research Institute, June 1968. Clearinghouse PB 192-311.

New York

New York. Legislature. Joint Legislative Committee on Metropolitan Areas Study. Municipal Cooperation: A Digest of New York State Law. Albany, New York: February 1963. 140 pp.

New York. Legislature. Joint Legislative Committee on Metropolitan Areas Study. Metropolitan Action: A Six-County Inventory of Practical Programs. Albany, New York: Janauary 1960. 141 pp. (Mimeographed).

New York State. Office for Local Government. Local Government Cooperation. Albany, New York: April 1963. 33 pp.

Southern Chatangua Regional Planning Board. Intergovernmental Cooperation Study for the Southern Chataugua Region. Lakewood, New York: 1974, NTIS PB 232-554.

North Carolina

The Water Facilities Function Project. Charlotte, North Carolina: USAC Project, 1972. NTIS PB 220-099.

North Dakota

Beck, R.E. "Drainage Law in North Dakota: An Overview", North Dakota Law Review, Vol. 47, No. 4, pp. 471-513. (Summer 1971).

Crockett, Richard B. An Analysis of Local Water-Related Districts in North Dakota. Fargo, North Dakota and Washington, D.C.: Water Resources Research Institute, North Dakota State University; Office of Water Resources Research, Department of the Interior, 1972. NTIS PB 236-814.

Ohio

Cochran, Robert D. "The Problem of Metropolitan Government in Ohio", Western Reserve Law Review. Vol. 7, (December 1955), pp. 87-93.

Craine, Lyle E. "The Muskingum Watershed Conservancy District: A Study of Local Control", Law and Contemporary Problems. Vol. 22, No. 3, (1957), pp. 378-404.

The Governmental Research Institute. Authorized Intergovernmental Cooperation at the Local Level in Ohio. Governmental Facts Number 62, December 20, 1962. Cleveland, Ohio: 1962. 5 pp. (Processed).

Holden, Matthew, Jr. Intergovernmental Agreements in the Cleveland Metropolitan Area. Cleveland, Ohio: Cleveland Metropolitan Services Commission, July 1958. 56 pp. (Mimeographed).

Ohio Department of Natural Resources. The Conservancy District Law (Outline and Text of Ohio Convercancy District Law). Columbus, Ohio: Division of Water.

Skinner, Calvin. Functional Integration Within a Metropolitan Area Through Intergovernmental Contracts and Transfers. Cincinnati, Ohio: Cincinnati Bureau of Governmental Research, June 1952. 7 pp. (Mimeographed).

Oregon

Bureau of Municipal Research and Service, University of Oregon. Local Intergovernmental Cooperation in the Tri-County Area. Information Bulletin No. 150, November 1966. Eugene, Oregon: 1966. 55pp. (Processed).

Hallmark, William L. "Oregon's Water Management Districts", Oregon Law Review (December 1967), pp. 16-70.

Pennsylvania

Blair, George S. Interjurisdictional Agreements in Southeastern Pennsylvania. Philadelphia, Pennsylvania: Fels Institute of Local and State Government, University of Pennsylvania, January 1960. 136 pp.. (Mimeographed).

"City and Suburbs Work Together for Sewage Disposal", Horizons for Modern Pennsylvania Local Government. Vol. IV, No. 3 (March 1957).

"Cooperative Agreements and Arrangements--Philadelphia and Other Governmental Jurisdictions (Formal and Informal by Function)", Pennsylvanian. December 1965, pp. 4-6.

Kelly, J. Martin, Jr. "617 Agreements Link 1,794 Municipal Units in Cooperative Action", Department of Internal Affairs Monthly Bulletin. Vol. 26, No. 7 (July 1958), pp. 1-9, 28.

Seyler, William C. "Municipal Cooperation in Action in Pennsylvania", Department of Internal Affairs Monthly Bulletin. Part 2, Vol. 29, No. 9 (September 1961), pp. 8-15.

Williams, Oliver P. Intergovernmental Cooperation for Disposal of Sewage: Southeastern Pennsylvania. Philadelphia, Pennsylvania: Institute of Local and State Government, University of Pennsylvania, 1961.

Wise, Sidney, ed. Selected Areas of Intergovernmental Cooperation. Harrisburg, Pennsylvania: Bureau of Municipal Affairs, Department of Internal Affairs, Commonwealth of Pennsylvania, 1962. 39 pp.

Virginia

Richmond Regional Planning District Commission. Land Use--Intergovernmental Relations in the Richmond Metropolitan Area. NTIS PB 231-588.

Washington

Campbell, Ernest H. Existing Authority for Intergovernmental Relations of Cities and Towns by Contract. Seattle, Washington: Bureau of Governmental Research and Services, University of Washington, May 1964. 21 pp. (Mimeographed).

Garvey, M.D. et al. An Analysis of the Law Governing Six Selected Washington Water-Oriented Special Districts, Commentary on Improving the Flood Associated Activities of the State of Washington. Pullman, Washington: State of Washington Water Research Center, June 1970.

Ittner, Ruth; Webster, Donald; Campbell, Ernest H.; and others. Government in the Metropolitan Seattle Area. Report No. 133. Seattle, Washington: Bureau of Governmental Research and Services, University of Washington, October 1956. 148 pp. (Mimeographed)

Rosenow, Bervely J. A Study of Various Procedures Utilized by Selected Water-Oriented Special Districts Which are Common to All of Them. Seattle, Washington: School of Law, Washington University. NTIS PB 195-828.

Wisconsin

Intergovernmental Cooperation Committee, Milwaukee Metropolitan Study Commission. Final Report on Intergovernmental Cooperation in Milwaukee County. Milwaukee, Wisconsin: April 1961. 77pp. (Mimeographed).

"Joint Municipal Services", The Municipality, League of Wisconsin Municipalities. Vol. 50, No. 5, (May 1955), pp. 93-94, 106.

Metro Study Commission Committee on Metro Functions. Report on Sewage Disposal in the Milwaukee Metro Area. Milwaukee: 1958.

Southeastern Wisconsin Regional Planning Commission. Water Law in Southeastern Wisconsin (Watershed Management and Pollution Controls). Technical Report No. 2, (1966), pp. 41-92.

QUESTIONS AND ANSWERS

(Following Andrew Waldo's paper "Intergovernmental Tangle Facing Stormwater Control")

Question (Doug Thompson, North Central Texas Council of Governments): You singled-out Montgomery County, Maryland as the richest county in the United States. You emphasized that they do not have adequate staff to enforce regulations, and you indicated that Montgomery County has a more effective program than Prince Georges County. My first question is what evidence is there that Montgomery County's program is effective? My second question relates to stormwater management--or ordinances and regulations for controlling non-point sources. I am curious about voluntary compliance by land developers who work cooperatively with either the councils of government or local governments, as opposed to regulation--which requires adequate staff, and which Montgomery County doesn't have.

Waldo: Montgomery County does have an effective program. Representatives of Prince Georges County told me that they do not have a coordinated program. The difference between the two counties goes back to the Civil War. Prince Georges County has, in many respects, been following Montgomery County. I wanted to use these as an example of two neighboring counties that have two completely different types of programs, leading to different results. You are right about ordinances and regulations. There are some cases where voluntary compliance by developers has been effective. But, I think it is necessary to have the ability to insure maintenance, as an example, to insure that detention facilities, once built, will be maintained and operated in an effective manner. I believe that regulation is a good way to accomplish this. The cities that I am familiar with that have passed these ordinances seem to have adopted a good method for assuring maintenance--by ordinance. Some of the cities that have adopted such ordinances are: Gainesville, Florida; Naperville, Illinois; and Joliet, Illinois. In these cities the ordinances have provided effective tools for solving many of the intergovernmental problems. These institutional problems and issues are very broad.

Question (Doug Thomson): What data or information do you have that shows that, as a result of Montgomery County's coordinated effort, they are successful and their problems are lessened, and that Prince Georges County's problems are not lessened?

Waldo: Montgomery County has entered into a study to determine the water quality impact. I believe that they found that they had some success. The relative merits of these methods are based on the techniques that Montgomery County is requiring of its developers. Those techniques have certain load reductions and, from looking at the areas under construction and the techniques employed, there seems to be a reduction of erosion and sediment delivery to the receiving water. My opinion is based on consideration of technical aspects, and it is not merely an arts and crafts viewpoint. The receiving water has benefitted from Montgomery County's coordinated program.

Question (Stephen Sowby, Mountainland Association of Governments, Provo, Utah): With all the fragmentation, duplication, overlapping, et cetera in many areas, what do you perceive as the obligation of planners, engineers or consultants who are involved in water quality? What obligation do we have to lead, help, push or shove elected officials to implement the plans that we develop?

Waldo: First, the obligations come from the intent for having 208 agencies. If you want to talk about the goals of Public Law 92-500, I think the obligation requires action, beginning with public participation and characterizing the problem so that one can confront some of the available solutions. I think that the obligation has to be carried forward, beginning with identification of the problem. Does the problem lend itself to the need for cooperation between various governments? Then, it is necessary to make the public aware of those problems and carry forward a program of action.

Question (Joe Bryan, Houston-Galveston Area Council of Governments): In our agency, we have a division of transportation planning as well as 208 planning. Do you see any cross-linkages between the two types of physical planning--such as in land-use management or parking lots?

Waldo: One part of EPA's Best Management Practice (BMP) will be looking at street sweeping. This requires consideration of traffic density and traffic routing patterns. This involves transportation planning. There must be some rapport between the two types of planning. You must have traffic density maps to determine some of the loading intensities on the streets. Yes, I think that the transportation plan has to form a part of the 208 plan because traffic densities increase the loading on the streets.

Question (Joe Bryan): What are the 208 implications and requirements of air quality planning?

Waldo: Perhaps John Kingscott of our EPA Washington, D.C. office may wish to respond to this.

John Kingscott: There are no set requirements. We are just looking for consistency.

Comment: The film we saw yesterday showed a Seattle Metro project in which a facility had been designed to serve both as a wastewater pumping station and a bus stop.

STATE/LOCAL INTERACTION IN STORMWATER MANAGEMENT*

BY

EUGENE T. JENSEN**

I. APPROACHING THE PROBLEM

STORMWATER MANAGEMENT PROBLEMS COMMONPLACE THROUGHOUT THE STATE OF VIRGINIA VARY GREATLY IN SIZE AND COMPLEXITY DEPENDING UPON GEOGRAPHY, THE SIZE OF THE COMMUNITY, AND DEGREE OF URBAN DEVELOPMENT. THE PUBLIC, AND PROBABLY THE PROFESSIONAL FRATERNITY, HAVE NOT UNDERSTOOD FULLY THE RELATIONSHIP BETWEEN DRAINAGE, FLOODING AND WATER QUALITY.

MANAGEMENT OF STORMWATER PROBLEMS IS DEPENDENT UPON A SEQUENCE OF EVENTS IN WHICH A GIVEN PROBLEM MUST BE IDENTIFIED AND DESCRIBED, ACCEPTED BY THE PUBLIC AS A PROBLEM IN NEED OF SOLUTION, DEVELOPMENT OF ALTERNATIVE SOLUTIONS TO THE IDENTIFIED PROBLEM, AND FINALLY, THE IMPLEMENTATION OF THE TECHNICAL SOLUTION.

THE EXTENT TO WHICH THE PUBLIC ACCEPTS PRESENCE OF A PROBLEM WILL PROBABLY BE TEMPERED BY THE DEVICE THROUGH

---

*Prepared for presentation at the EPA Urban Stormwater Management Seminar, Atlanta, Georgia, November 6, 1975.

**Prepared by Eugene T. Jensen, Executive Secretary, Virginia State Water Control Board, P.O. Box 11143, Richmond, VA 23230

WHICH IT IS BROUGHT TO THEIR ATTENTION. EXPERIENCE IN VIRGINIA SUGGESTS THE FOLLOWING MECHANISMS, IN ORDER OF PRIORITY, WILL GENERATE THE PUBLIC ACCEPTANCE NECESSARY TO REACH THE PROBLEM SOLUTION AND IMPLEMENTATION STAGES:

SEVERE FLOODING OR DRAINAGE PROBLEMS. FLOODING AND DRAINAGE PROBLEMS MAY CAUSE SEVERE FINANCIAL AND SOCIAL PROBLEMS FOR INDIVIDUALS AND BUSINESSES IN THE AFFECTED LOW-LYING AREAS OR FLOODPLAINS. ADDITIONALLY, SEVERE FLOODING OF ARTERIAL HIGHWAYS MAY INTERFERE WITH TRANSPORTATION AND INCONVENIENCE THE ORDERLY MOVEMENT OF TRAFFIC DURING PEAK HOURS. THE FREQUENCY OF INTERFERRENCE, THE AVAILABILITY OF ALTERNATE ROUTES, AND THE DEGREE OF INCONVENIENCE WILL ALL AFFECT THE NATURE OF PUBLIC RESPONSE AND ACCEPTANCE.

WATER SUPPLY. RAPID DEGRADATION OF WATER QUALITY REFLECTED IN TASTE, ODOR OR COLOR PROBLEMS IN MUNICIPAL WATER SUPPLY WILL QUICKLY SOLIDIFY WIDESPREAD PUBLIC SUPPORT FOR STORMWATER AND RUNOFF MANAGEMENT PROGRAMS. UNFORTUNATELY, OR PERHAPS FORTUNATELY, THE WATER SERVICE AREA MAY NOT BE THE SAME AS THE WATERSHED AREA, THEREBY RAISING INTERESTING COST AND BENEFIT RELATIONSHIP PROBLEMS. SEDIMENTATION IN RESERVOIRS IS A MORE INSIDIOUS PROCESS WHICH MAY EVENTUALLY GENERATE PUBLIC ACCEPTANCE AND SUPPORT THROUGH LOSS OF RESERVOIR CAPACITY AND INTERFERRENCE WITH WATER SUPPLY DURING PERIODS OF DROUGHT.

DOWNSTREAM WATER QUALITY. INTERFERRENCE WITH DESIRED DOWNSTREAM WATER USES, NOTABLY FISHING AND RECREATION, MAY BE QUITE EFFECTIVE IN GENERATING COMMUNITY INTEREST IN PROBLEM ACCEPTANCE AND SOLUTION, PARTICULARLY IF THE AFFECTED POPULATION MAKES USE OF THE DOWNSTREAM FISHING OR RECREATIONAL USES.

ADMINISTRATIVE DECLARATION. A LEGISLATIVE OR ADMINISTRATIVE DETERMINATION, WHICH MAY AT TIMES SEEM TO THE PUBLIC MORE IN THE NATURE OF A REVELATION, THAT A PROBLEM EXISTS IS PROBABLY LEAST EFFECTIVE IN GENERATING SUPPORT. THE PUBLIC IS INURED AGAINST SUCH BUREAUCRATIC ACTIONS AND THEY ARE SUSPICIOUS OF THE MOTIVATION OF THE BUREAUCRATS AND LESS THAN ANXIOUS TO COMMIT FINANCIAL RESOURCES TO CORRECTION OF A PROBLEM WHICH MAY BE APPARENT ONLY TO THOSE IN THE FAR-AWAY STATE OR NATIONAL CAPITAL.

ONE OF THE SEVERE CONSTRAINTS PLACED ON ALTERNATIVE SOLUTIONS IS COST EFFECTIVENESS. ANOTHER IS ACCEPTABILITY BY LOCAL CITIZENS. THESE TWO CONSTRAINTS ARE CLOSELY RELATED AND BEAR ON THE SUBJECT AT HAND. VIRGINIA HAS NOT FOUND ALL OF THE ANSWERS, PERHAPS NOT ANY, BUT WE BELIEVE WE ARE HEADED IN THE RIGHT DIRECTION. A KEY ASPECT OF GETTING THOSE ANSWERS IS STATE/LOCAL INTERACTION. WE ARE UNDERTAKING A DIVERSITY OF APPROACHES. MOST IMPORTANT, WE HAVE LEARNED THE NEED FOR FLEXIBILITY IN OUR STATE/LOCAL RELATIONSHIPS. RECOGNIZING THAT EACH AREA HAS UNIQUE

PROBLEMS, STUDIES AND SOLUTIONS ARE BEING APPROACHED ON A CASE-BY-CASE BASIS. WE TRY TO KEEP FOREMOST IN OUR THOUGHTS THE OVERALL WELFARE OF THE PEOPLE AND THEREFORE PLACE EMPHASIS ON LOCAL ACTION WHERE FEASIBLE.

RESPONSIVE STATE/LOCAL INTERACTION WAS FACILITATED IN VIRGINIA BY LEGISLATIVE ACT WHICH ESTABLISHED PLANNING COMMISSIONS COMPOSED OF LOCAL ELECTED OFFICIALS. THE STATE IS DIVIDED INTO TWENTY-TWO MULTI-COUNTY PLANNING DISTRICTS, EACH WITH ITS OWN COMMISSION. THE PLANNING DISTRICT COMMISSION IS RESPONSIBLE FOR OVERALL LOCAL PLANNING IN THEIR DISTRICT. THE STATE WATER CONTROL BOARD IS ORGANIZED ALONG A SOMEWHAT PARALLEL STRUCTURE OF REGIONAL OFFICES TO WORK DIRECTLY WITH LOCAL PLANNERS AND OTHER OFFICIALS.

VIRGINIA IS A COMPLEX STATE, WITH GEOGRAPHY RANGING FROM STEEP MOUNTAIN VALLEYS TO FLAT COASTAL PLAINS. IN URBAN DEVELOPMENT, IT RANGES FROM THE RAPIDLY GROWING WASHINGTON METROPOLITAN AREA TO THE SMALL COMMUNITIES WHICH HAVE CHANGED LITTLE IN POPULATION SINCE THE REVOLUTION.

CONTROL OF POLLUTANTS FROM NON-POINT SOURCES IS A REASONABLY STRAIGHT-FORWARD PROPOSITION, GENERALLY INVOLVING THE CONSTRUCTION OF SEWERS AND A SEWAGE TREATMENT PLANT. HOWEVER, THE MANAGEMENT OF STORMWATER, RECOGNIZING BOTH QUALITY AND QUANTITY PROBLEMS, PRESENTS A WIDE VARIETY OF TECHNICAL AND POLITICAL PROBLEMS.

II. EXAMPLES OF SOME MAJOR PROGRAMS BEING CONDUCTED IN VIRGINIA

THE OCCOQUAN RESERVOIR IS LOCATED IN A RAPIDLY URBANIZING AREA OF NORTHERN VIRGINIA AND IS THE PRIMARY WATER SUPPLY FOR THE FAIRFAX COUNTY PORTION OF THE METROPOLITAN WASHINGTON D.C. AREA. IT HAS A DRAINAGE AREA OF APPROXIMATELY 570 SQUARE MILES, IMPOUNDS 9.8 BILLION GALLONS OF WATER, AND HAS AN ESTIMATED SAFE YIELD OF 65 MGD. THE STATE WATER CONTROL BOARD RECOGNIZED A PROBLEM WITH WATER QUALITY DUE TO POINT AND NONPOINT SOURCE POLLUTION. IN 1971 A POLICY WAS ESTABLISHED WHICH REQUIRES ALL WASTE WATER TREATMENT TO BE CONSOLIDATED INTO TWO REGIONAL PLANTS AND TO PROVIDE A HIGH LEVEL OF WASTE TREATMENT, A MONITORING PROGRAM WAS ESTABLISHED AS A JOINT STATE/LOCAL PROJECT. ALL AREAS IN THE WATERSHED AND THE RESERVOIR OWNER SHARE THE COST OF MONITORING. THE POLICY PREVENTS ANY NEW SEWER HOOKUPS WITHIN THE WATERSHED UNTIL THE EFFECTIVENESS OF POLLUTION CONTROL MEASURES HAVE BEEN ASSESSED THROUGH THE MONITORING PROGRAM. A RECENTLY ESTABLISHED 208 AGENCY WILL ALSO PARTICIPATE IN THE MONITORING PROGRAM. THE BOARD HAS BEEN HEAVILY INVOLVED IN ENCOURAGING LOCAL GOVERNMENTS TO ENFORCE SEDIMENTATION CONTROL ORDINANCES.

FAIRFAX COUNTY COMPRISES AN AREA OF APPROXIMATELY 400 SQUARE MILES IN THE SOUTH PORTION OF THE WASHINGTON

METROPOLITAN AREA AND HAS A POPULATION OF JUST OVER ONE HALF MILLION. THE COUNTY HAS BEEN WORKING WITH STORMWATER DRAINAGE PROBLEMS SINCE THE LATE 1950'S. IN 1971, THE VOTERS APPROVED AN $11 MILLION BOND ISSUE FOR STORM DRAINAGE CONTROL. AN ENGINEERING CONSULTANT WAS HIRED ON A FIVE-YEAR CONTRACT TO DEVELOP THE MANAGEMENT PROGRAM. SOME OF THE OUTPUT TO DATE HAS BEEN A COMPUTERIZED STORMWATER MODEL FOR ASSUMPTIVE LAND USE IN THE DRAINAGE BASIN; AN ENVIRONMENTAL BASELINE STUDY WHICH HAS WIDE APPLICATION, ENABLING MEASUREMENT OF FUTURE ENVIRONMENTAL CHANGES RESULTING FROM DEVELOPMENT; METHODOLOGY FOR CALCULATING SOIL LOSS BEFORE AND AFTER DEVELOPMENT; NEW DRAINAGE CODES FOR THE COUNTY; AND A METHOD TO QUALITATIVELY CORRELATE EFFECTIVENESS AND COSTS OF STORMWATER CONTROLS IN VARIOUS WATERSHEDS. AN EXCITING FEATURE AS YET NOT ADEQUATELY TESTED WILL PERMIT DEVELOPMENT OF PERFORMANCE STANDARDS RELATED TO MAXIMUM SOIL LOSS PERMITTED. UNDER CURRENT COUNTY REGULATIONS, DEVELOPERS OF LESS THAN ONE SQUARE MILE AREA MUST SUBMIT STORMWATER CALCULATIONS FOR PRIOR APPROVAL TO COUNTY ENGINEERS. THE COUNTY HAS RIGOROUSLY RESTRICTED FLOOD PLAIN DEVELOPMENT DURING THE PAST TWO DECADES. SINCE 1972, THE COUNTY HAS HAD A POLICY OF SITE RETENTION WHICH LIMITS OFFSITE DRAINAGE TO PRE-DEVELOPMENT LEVELS. THEY HAVE DEVELOPED A SITE RETENTION DEFICIENCY INDEX WHICH ALLOWS ECONOMIC EFFECTS OF THIS POLICY TO BE DETERMINED.

THE FOUR MILE RUN DRAINS A SMALL FOURTEEN AND ONE-HALF SQUARE MILE AREA IN THE CITY OF ALEXANDRIA AND FAIRFAX COUNTY IN THE WASHINGTON METROPOLITAN AREA. THE ENTIRE DRAINAGE AREA, WHICH HAS BECOME COMPLETELY URBANIZED IN RECENT YEARS IS PART OF A FEDERAL FLOOD CONTROL PROJECT. AT THE URGING OF THE STATE, MANY MEETINGS WERE HELD BETWEEN LOCAL, STATE AND FEDERAL OFFICIALS WHICH RESULTED IN STORM-WATER AND SEDIMENT CONTROL BEING INCLUDED AS AN INTEGRAL PART OF THE FLOOD CONTROL PROJECT. AS A UNIQUE "FIRST" IN THE STATE OF VIRGINIA, AND PERHAPS IN THE NATION, LOCAL OFFICIALS DEVELOPED A BASIN-WIDE RUNOFF CONTROL MANAGEMENT PROGRAM. THIS PROGRAM CONTAINS UPSTREAM LAND USE CONTROLS WHICH REQUIRE NEW DEVELOPMENTS TO INSTITUTE CONTROLS WHICH ASSURE THAT TOTAL FUTURE RUNOFF WILL NOT EXCEED DESIGN FLOW.

THE RIVANNA RESERVOIR IS THE PRIME SOURCE OF WATER FOR CHARLOTTESVILLE AND SURROUNDING ALBEMARLE COUNTY IN CENTRAL VIRGINIA JUST EAST OF THE BLUE RIDGE MOUNTAINS. THIS IS A DEVELOPING AREA AND THE SEAT OF THE UNIVERSITY OF VIRGINIA. THE LOCAL CITIZENS WERE SHOCKED TO FIND LARGE AREAS OF ALGAE BLOOMS DURING THE THIRD SUMMER AFTER THE RESERVOIR WAS FILLED. THE PROBLEM HAS BECOME SO SEVERE THAT THE RESERVOIR IS VIRTUALLY USELESS AS A WATER SUPPLY DURING THE SUMMER MONTHS OF LOW FLOW. THE CITIZENS DID NOT WAIT FOR FEDERAL GOVERNMENT ACTION, BUT INSTIGATED A WATERSHED STUDY ON THEIR OWN INITIATIVE AS A COMBINED FEDERAL-STATE-LOCAL PROJECT. THE COUNTY HAS IMPOSED A LIMITED MORATORIUM ON NEW BUILDING UNTIL THE PROBLEMS CAN BE ASSESSED.

LYNCHBURG AND RICHMOND HAVE COMBINED STORMWATER AND SANITARY SEWERS WITH RESULTANT BY-PASS OF UNTREATED WASTEWATER INTO RECEIVING WATERS OF THE JAMES RIVER DURING STORM OVERFLOW PERIODS. LYNCHBURG IS A CITY OF SOME 55,000 POPULATION LOCATED JUST BELOW THE UPPER THIRD OF THE 240 MILE LONG JAMES RIVER. RICHMOND, WITH A QUARTER OF A MILLION POPULATION, IS LOCATED AT THE UPPER ESTUARIAN REACH OF THE JAMES RIVER, THE STATE CAPITOL AND HIGHLY INDUSTRIALIZED. 201 FUNDED STUDIES ARE IN PROGRESS TO ASSESS THE MAGNITUDE OF THE PROBLEMS. THE RICHMOND STUDY WILL PROVIDE INPUT TO THE 208 PLANNING BEING CONDUCTED THERE. THE STATE HAS ESTABLISHED CONSTRUCTION GRANT PRIORITIES FOR BOTH CITIES.

THE STATE LEGISLATURE RECENTLY PASSED A LAW WHICH ESTABLISHES MINIMUM REQUIREMENTS FOR EROSION AND SEDIMENT CONTROL ORDINANCES TO BE ENACTED BY ALL LOCAL POLITICAL SUBDIVISIONS OF THE STATE BY 30 JUNE 1976. THE PURPOSE OF THE ACT WAS TO ENCOURAGE LOCAL GOVERNMENTS TO DEVELOP THEIR OWN COMPREHENSIVE PLANNING PROCEDURES WHICH INCORPORATE CONTROLS OF STORMWATER DRAINAGE. WHERE LOCAL JURISDICTIONS FAIL TO ACT, THE STATE LAW WILL PREVAIL AND WILL BE ENFORCED BY THE STATE.

IN VIRGINIA 208 AGENCIES HAVE AN ACTIVE ROLE IN EVALUATING THE STORMWATER RUNOFF PROBLEM. FIVE INTRA-STATE AREAS HAVE BEEN DESIGNATED: HAMPTON ROADS, RICHMOND-CRATER, ROANOKE, FREDERICKSBURG AND SOUTHWEST VIRGINIA. TWO INTER-STATE AREAS HAVE ALSO BEEN DESIGNATED; NOTHERN VIRGINIA WITH THE WASHINGTON

METROPOLITAN AREA AND THE BRISTOL CITY AREA WITH THE STATE OF TENNESSEE. THE SOUTHWEST VIRGINIA AREA WAS DESIGNATED SPECIFICALLY FOR CONTROL OF RUNOFF FROM COAL MINE OPERATIONS. THE STATE WAS INSTRUMENTAL IN GETTING EPA TO ACCEPT THIS AS A UNIQUE WATER QUALITY CONTROL PROBLEM.

THE ROANOKE 208 AGENCY HAS PROGRESSED FURTHEST OF THOSE DESIGNATED. THE CONSULTANT, MOORE-GARDNER AND ASSOCIATES, HAS COMPLETED PRELIMINARY SAMPLING AND IS USING THE STORM COMPUTER PROGRAM FOR ANALYSIS. THIS IS THE STORAGE, TREATMENT, OVERFLOW AND RUNOFF MODEL, ADAPTED FROM THE ORIGINAL DEVELOPED BY WATER RESOURCES ENGINEERS, INCORPORATED FOR EPA AND THE U.S. ARMY CORPS OF ENGINEERS.

BRYAN PARK, A LARGE PUBLIC PARK, IS LOCATED IN NORTHERN RICHMOND CITY AND HENRICO COUNTY. IT CONTAINS A LAKE WHICH DRAINS APPROXIMATELY 20 SQUARE MILES OF RAPIDLY URBANIZING AREA. IT IS ALSO SITUATED AT THE JUNCTION OF THREE INTERSTATE HIGHWAYS: I-95; I-64; AND I-195. STORM WATER IS COLLECTED IN THREE CREEKS WHICH EMPTY INTO THE LAKE. A RECENTLY BROKEN DAM UPSTREAM IN ONE OF THE CREEKS IS ALLOWING ACCUMULATED SILT TO WASH DOWN, BLOCKING STREAM CHANNELS THROUGH THE POND. THE PROBLEM IS COMPLICATED BY THE FACT THAT COMBINED SEWERS BACK UP RAW SEWAGE INTO BASEMENTS OF DWELLINGS. TO ALLEVIATE THAT HEALTH PROBLEM, HENRICO COUNTY HAS EXERCISED THE PRACTICE OF PUMPING OUT MAN HOLES. FECAL COLIFORM BACTERIA HAVE BEEN

FOUND IN INCREASING AMOUNTS IN THE LAKE IN BRYAN PARK. THE STATE WATER CONTROL BOARD IS MONITORING THESE WATERS AND IS ENCOURAGING THE RICHMOND-CRATER 208 AGENCY TO UTILIZE THIS AREA AS PART OF THEIR STUDY OF NON-POINT SOURCES OF POLLUTION. LOCAL CITIZENS HAVE ALSO FORMED A BRYAN PARK CIVIC ASSOCIATION WHICH IS ALSO TRYING TO REMEDY THE SITUATION. THE STATE POSITION HAS BEEN TO HELP THROUGH MONITORING AND TO ENCOURAGE LOCAL ACTIONS TO CORRECT THE PROBLEMS.

NORFOLK IS AN OLD CITY OF SOME 308,000 POPULATION LOCATED IN THE RAPIDLY URBANIZING AREA OF HAMPTON ROADS IN TIDEWATER VIRGINIA. HAMPTON ROADS IS A LARGE ANCHORAGE LOCATED BETWEEN THE MOUTH OF THE JAMES RIVER AND THE LOWER CHESAPEAKE BAY. THE ELIZABETH RIVER, DRAINING PORTIONS OF THE DISMAL SWAMP, FLOWS THROUGH THE CITY AND EMPTIES INTO THE HAMPTON ROADS. NORFOLK, AS THE LONG STANDING HOME OF THE ATLANTIC FLEET OF THE U.S. NAVY AND THE LARGEST NAVAL BASE ON THE EAST COAST, ALSO HAS A MAJOR SHIPYARD. IT IS A GROWING COMMERCIAL SEAPORT, AVERAGING NEARLY 50 MILLION TONS OF TRAFFIC A YEAR, 70% OF WHICH IS FOREIGN TRADE. STORM WATER DRAINAGE CREATES SEVERE PROBLEMS IN THE CITY. INFLUENCED BY TIDAL FLUCTUATIONS, EVEN AN AVERAGE SUMMER SHOWER CAUSES WIDESPREAD STREET FLOODING. THE AVERAGE ELEVATION OF THIS FLAT AREA IS 10-25 FEET ABOVE MEAN SEA LEVEL AND MINIMIZES THE EFFECTIVENESS OF GRAVITY FLOW DRAINAGE. THE WATER QUALITY PROBLEM IS FURTHER

COMPLICATED BY QUALITY OF WATERS FLOWING INTO THE AREA, CONTAMINATION BY PORT ACTIVITIES AND LACK OF ADEQUATE FLUSHING REGIME. THE STATE WATER CONTROL BOARD WAS INFLUENTIAL IN EARLY DESIGNATION OF THIS AREA FOR 208 PLANNING. IN ADDITION, THE VIRGINIA INSTITUTE OF MARINE SCIENCE HAS BEEN CONDUCTING VARIOUS MONITORING AND MODELLING PROGRAMS IN THE AREA. A MAJOR THRUST OF 208 PLANNING WILL BE THE STORM WATER MANAGEMENT.

III. SUMMARY

AS STATED IN THE BEGINNING, WE DON'T HAVE THE ANSWERS. THE FOREGOING HAS BRIEFLY HIGHLIGHTED SOME OF OUR MAJOR PROBLEM AREAS AND DEMONSTRATED DIFFERING APPROACHES USED. WE TRY TO WORK DIRECTLY WITH LOCAL OFFICIALS AND JURISDICTIONS, PROVIDING GUIDANCE AND ASSISTANCE. FLEXIBILITY IS THE KEY, FIT THE APPROACH TO THE UNIQUENESS OF THE PROBLEM. MOST IMPORTANT -- UNDERSTAND THE PROBLEM, IF ANY, BEFORE SEEKING PUBLIC ACCEPTANCE OR PRESCRIBING A SOLUTION!

THE ROLE OF THE FEDERAL AGENCIES IN THE STORMWATER MANAGEMENT SYSTEM HAS NOT BEEN DISCUSSED; HOWEVER, IT MUST BE RECOGNIZED THAT AT LEAST SIX FEDERAL AGENCIES ARE DIRECTLY INVOLVED IN STORMWATER MANAGEMENT PROGRAMS AND THAT EACH HAS ITS OWN LOCAL CLIENTELE. THESE FEDERAL PROGRAMS, WHICH ARE CARRIED OUT BY THE CORPS OF ENGINEERS, THE SOIL CONSERVATION SERVICE, THE FOREST SERVICE, THE BUREAU OF LAND MANAGEMENT, THE

ENVIRONMENTAL PROTECTION AGENCY AND HOUSING AND URBAN DEVELOPMENT, MAY NOT BE WELL COORDINATED WITH EACH OTHER AND MAY COMPLICATE STATE/FEDERAL RELATIONS. THE RESPECTIVE ROLES OF THESE AGENCIES SHOULD BE CONSIDERED VERY CAREFULLY BY STATE AND LOCAL OFFICIALS AS THEY ADDRESS THEMSELVES TO THE ASSESSMENT AND RESOLUTION OF STORMWATER MANAGEMENT PROBLEMS.

LEGAL ASPECTS OF URBAN STORMWATER MANAGEMENT

by W. Joseph Shoemaker
Shoemaker and Wham, Attorneys
Denver, Colorado

I am here today to speak on both the legal and financing aspects of urban stormwater management. I don't believe that you can finance stormwater projects without a knowledge of the legal aspects involved.

There is only one thing that everyone agrees with concerning stormwater, and that is that "stormwater runs downhill". The inter-play between governments is something that one must understand in order to make accomplishments in stormwater management. Local governments are most independent, ranking second only to farmers. You must let local officials know that you spent a lot of time thinking about what their problems are in order to persuade them concerning suggested approaches. I was the director of public works for the City and County of Denver from 1959 to 1962 and I couldn't solve drainage, and that is why I got interested in it. You must understand the legal background to know why solutions to drainage are so difficult.

This is the way I look at stormwater management from a legal standpoint.(1) Historically, the problems of drainage belong to private property owners. They do not belong to government. In the United States, different states take different approaches to stormwater--civil law doctrine, common-law doctrine, modified civil-law doctrine and the modified common-law doctrine. Simply explained, the common law doctrine says water is a common enemy and you can do anything you wish to protect your own property. The civil law theory is that the property owner on top of the hill has an easement to run stormwater onto any property lying below. Most courts, certainly the Colorado Supreme Court, and most jurisdictions have adopted a modified civil law version which is that the servient owner must take the water, but not to a degree which will cast more water downhill on him than would have naturally flowed. This is the way the Colorado Supreme Court has put it; namely, that the lower owner must take the water, but not more water than would naturally flow without the upper owner providing for the carrying off of that extra water. So, the obvious situation in an urban area, where everyone goes out and blacktops their lots, et cetera, is that they have changed the amount of water that flows downhill from what flowed before.

Now, when one tries to translate that legal doctrine into financing, the owner sitting at the top of the hill says: The hell with it, I ain't got no problem! If anyone is dumb enough to live at the bottom of a hill, that's his problem. I was smart enough to live uphill, so if you think I am going to take care of that jerk, you have another guess coming."

When you get to a special assessment district, which is the traditional method of financing a local drainage improvement, you must prove "benefit" to the owner that you want to assess. When you come into court to assess an upper owner, the law traditionally says that the meaning of benefit is "increased value" of the property. The upper owner usually claims that his property value has not been increased, even though a million-dollar storm sewer may have been constructed below his property to collect his surface drainage. This is the situation that most local officials encounter today.

But I submit to you that the law is different than this and that there are other legal benefits that increase the value of property. I wrote an article in the Denver Law Journal (2) concerning "benefits". Based on that article, I succeeded in getting the Colorado statutes changed to define "benefits" different from the definition of the courts. We have six or seven different methods of defining benefits. One is the fact that somebody takes the extra runoff resulting when an owner of upper lying property blacktops his lot. The fact that the owner uphill discharges it downstream requires that the runoff be handled some way. It is similar to a utility operation, such as refuse, which somebody has an obligation to handle for health and safety reasons.

You must understand the interplay between streets and drainage and the latest theory that the streets are polluting the waters. I wish to tell you that this is a "fact" question, and I have not yet seen anyone devise a factural method for determining that; although, I have read many theoretical articles on the subject. The Urban Drainage and Flood Control District in Denver has hired the U.S. Geological Survey to come up with an approach on what is the pollutant runoff from streets into our streams. This is a fact question that is far beyond the basic legal theory that I am addressing today.

Drainage has always been a private property matter between two property owners. So, if my house was flooded because an upper owner sent more water downhill than would naturally flow, I could sue that upper owner. On the other hand, if I am the uphill owner and a downstream owner dams up his property so that the water backs up on me, I can sue the owner downhill because there is no right, in Colorado, for an owner to back water up on another owner's property-since Colorado does not follow the common law theory.

Then, you merge this into an urban area where you have 5,000 houses in a drainage basin. Just identifying a drainage basin is a fact question. Up until five years ago, we hadn't done that in this area. It wasn't until Denver realized that no jurisdiction could solve a drainage problem by itself that we went to the State Legislature and requested a special district, or governmental entity, to handle the drainage problems. So, the State formed a 1,280 square mile district which was the urban and urbanizing part of the Greater Denver area. After six years, this District has completed more than 50 master plans identifying where flood plains are. And now, the District is studying what pollutes the rivers from drainage.

This brings me to the way lawyers work, using analogies. To get facts across to a lay person, a good method is to give an analogy. I say there is an analogy between "flood plain" management and the "pollution coming off streets which enters streams". Let's start with what I think are two of the best pieces of legislation that the Congress has ever enacted. Congress determined that there are two national goals: one is clean, natural water by 1985; the other is that the floodplains should be unobstructed for a 100-year storm. The latter is the flood insurance program. In one case, we have the EPA; in the other case, we have the FIA. From a local/state standpoint, we have problems with both of these federal agencies. However, I agree with these two goals because I think our water should be clean and I do not think anyone should buy or build a house in a floodplain.

That's the analogy! We have two things going down the road at the same time, and you must back up and say both of these, which involve stormwater runoff, are based on the fact that, up until a few years ago, all the stormwater problems were simply "private property-owner" problems. If the guy pumped sewage into the river, who gave a damn? Nobody owned the fish. If someone was getting their drinking water from the river, they had a problem. Or, if someone was using the river for irrigation, he may have a problem. Similarly, for persons building, or buying property, in the floodplain, "caveat emptor" (let the buyer beware)! It wasn't until we got 5,000 owners in a drainage basin that people really began complaining to the local government. They would ask for something to be done, but did not want to pay for the solution. Neither were the people owning property at upper elevations agreeable to pay the costs for solutions. As a result, nothing would happen. It wasn't until public works people and city engineers got enough complaints that they finally got into providing solutions.

When you start researching the legal obligation of some public official who gets into an area where he doesn't belong, you will find that any municipal official will be held for his negligence. He will not come under the doctrine of sovereign immunity; and he will not be able to say that he just operates as a public official, because he doesn't have an obligation to operate as a public official in this field. So, when he gets into a proprietary rather than a governmental function, he had better be sure he is right. If he builds a storm sewer that is now the right size, of if he builds something that is faulty, he will be held for his negligence. From a public official's standpoint, you would normally ask "why should I do anything?"

Society has changed from a "care-nothing" attitude about a neighborhood or river to a "care-something" attitude. Three years ago, the City of Denver had spent well over a million dollars studying what to do about the South Platte River, but nobody did anything. I would like you to go down to the 15th Street Bridge and see what has been done in improving the South Platte River along a one-mile stretch from Speer Boulevard to the 20th Street Viaduct. I think that you will enjoy it. My ultimate solution to the stream pollution problem is to build trails and get a cadre of citizens using the trails and looking at the pollution of the streams. They will then point their finger at the polluter and the jerk who is living in the flood plain. By public opinion and support, something will then be done.

Following that line of action, we got the Drainage District established and prepared master plans for 50 drainage sub-basins. We now know where the floodplains are in 50 of the 300 drainage basins in this 1,280 square mile area. We know the facts! If you don't know the facts, don't try to get a private property owner to do something--and I include a city as a private property owner. You, at the EPA, are coming in here telling the City and County of Denver what they ought to do on the River. You are telling the State of Colorado what it ought to do, because Congress said that's what you should do. Well, you had better know what the facts are before you ask anything of the State, the City and County of Denver, or Joe Smith, who likes to float in the River, or live down there. From a legal standpoint, you must know what the facts are and you must identify the problem, or how long a solution will take, or what the ultimate cost will be, or who will pay.

Local government must monitor the pollution of local streams. Neither the State, nor any federal agency, will ever monitor all the 300 drainage subbasins. Two sessions ago the State of Colorado passed a major land-use bill (House Bill 1041), and I had something to do with that. The bill requires local governments to identify, designate and regulate certain areas of statewide interest. Floodplain hazards are right up at the top of the list.

From a legal standpoint, you must realize that you are working in an area of private property rights; but, if health and safety are involved, the police power comes into effect. Government was formed for the health, safety and well-being of its citizens. Government has forgotten that, because it gets into everything else. When you are working on drainage, you are working on "fundamentals", as far as I am concerned. Even though we have private property rights in terms of surface water coming down, if you, factwise, can prove that someone's life is at stake, you can regulate the floodplain. So, when someone tells me that I am taking his property without compensation, I say, "The hell I am! All I am doing is identifying a hazardous area. If you think you have a right, Mr. Developer, to sell that piece of property to some unsuspecting person on a sunny day, you have another guess coming! And if you think, Mr. Plant Manager, that you have a right to pump your sewage into the river, you have another guess coming, because you don't! And, Mr. City, if you think you have a right to do with your property what these private property owners are doing, you don't!"

The first place to make a record is at the local government level, which should get its house in order. It should not be polluting the river. Secondly, city facilities should not be built in floodplains. Until government sets an example, I don't think you will force property owners to do anything. Action will then only come by harassment and compromise.

You should proceed with the knowledge that you are dealing with the health and safety of people. Then, you should identify what the actual problem is. Most engineers and planners don't really know what the problem is! They don't know what the real world is like in terms of going to court and, on a legal basis, having some judge or jury rule in their favor. You shouldn't start anything unless you are prepared to carry it to its ultimate conclusion, because you are almost worse off by losing than never having started at all. If you don't have your facts right, you will lose 999 times out of a thousand.

Once you have the facts, you need a plan. The plan involves many things Is it legal? How long will it take? What will it cost? Will it actually solve the problem, or are we just wasting the taxpayers' money? If you can't sell solutions to drainage on a cost-benefit basis, you won't be successful. If someone can't say,"It is beneficial to have clean water", then you won't have clean water. I think Congress has said that it is a goal that we should have clean water. I would like to argue why I think the rivers ought to be clean and why people should not live in a floodplain. In both cases, I can argue on the basis of health and safety.

Then, it is necessary to get financing, and later to maintain the facilities. Maintenance is usually a local government function. How long should the river be clean? For one day? Or, for 24 hours of each day from now on, ad infinitum? Is that what the goal of Congress is? I believe that this is the goal! The only way to assure that this goal is being met is to provide monitoring on some basis other than by routine sampling methods. It is also necessary to know where the floodplain is. I usually depend on engineers for the latter information, but engineers sometimes differ in their answers concerning the location of the floodplains.

This stormwater management area is an intermixture of everything, and we must realize that we are dealing with various federal, state and local agencies--such as the EPA, HEW, HUD, FIA, USGS, Corps of Engineers, the Bureau of Outdoor Recreation, and Congress; and state agencies such as the Department of Health, the Water Quality Control Commission, the Water Conservation Board, and the State Legislature; and agencies of the City and County (of Denver) such as the Wastewater Control Department, Department of Health, Urban Drainage and Flood Control District, the Department of Public Works, and others. Everybody is in the act and few are doing anything about the stormwater problems. They are just thrashing around! If you don't have all the cobwebs out, you will not end up solving anything.

REFERENCES

1. Shoemaker, W. Joseph, "An Engineering-Legal Solution to Urban Drainage Problems", Denver Law Journal, Vol. 45, 1968, pp 381-398
2. Shoemaker, W. Joseph, "What Constitutes Benefits for Urban Drainage Projects", Denver Law Journal, Vol. 51, No. 4, 1974, pp 551-565

QUESTIONS AND ANSWERS

(Following W. J. Shoemaker's talk "Legal Aspects of Urban Stormwater Management")

Question: I work in an area just north of Denver, in Weld County and Larimer County, where we have a very complex hydrologic region and, superimposed on that, many problems of irrigation and return flows and runoff. Lacking facts, there is a lot of speculation as to whether or not we will ever be able to achieve either of the two national goals you mentioned, short of tremendous economic impacts. How does that interface with the goals that you believe in so firmly?

Answer: I think that you are presenting the real world the way it is. You must deal with the situation as it is. I don't believe that anyone can set the clock back. From a governmental enforcement standpoint, most laws "grandfather in". As I said earlier, it is necessary to identify the problems and their sources, probably through a monitoring program. Even though Congress established these goals, they are just that--goals and objectives. I don't think that they will be completely enforced by 1985.

Question: Do you believe in the application of uniform water quality standards nationwide?

Answer: First of all, you must define a navigable river. This leads to many definitions. I don't think the same standards should apply to the Platte River that apply to the Mississippi River. I think the standards should be set, based on the topography and local conditions. Maybe a minimum standard could be put in effect.

Question: (Michael Seaman, Snomish County, Washington): You said that, in order for a 208 plan to be successful, the plan must demonstrate, very clearly, the benefits to be derived from carrying out the plan. Benefit/Cost analysis, as we know, is a very "iffy" sort of thing, subject to different interpretation, and it is difficult to quantify the benefits.

Answer: I don't think it is difficult to quantify the basic benefits. Perhaps you are talking about "indirect" benefits. I think that "direct" benefits are not hard to quantify.

Question: When you say that a plan should have benefits, are you referring to concise dollar amounts?

Answer: Yes! But I not only attribute benefits to increases in property value, but to other things as well. Somebody taking my water is a benefit, the same as someone removing and hauling trash from my house. I think a dollar value could be placed on the potential use of the Platte River for recreational purposes. For example, I am planning a linear park 200 feet wide extending for 10 miles along the Platte River through Denver. This park will have a definable area, extent, and value; and people will understand this. In this way, I can translate to the public the need for keeping the Platte up to a certain reasonable quality standard. Then, the taxpayer will be willing to pay for it. I think we could assess the cost on the basis of who is causing the problem.

Question: (Andy Andrews, Denver): What are your plans to broaden the scope of studies made by the Urban Drainage and Flood Control District in Denver, to include water quality investigation?

Answer: The District has contracted with the U.S. Geological Survey to identify the extent of the urban runoff water quality problem. The due date of the study report is about March 1976. When that information has been received and accepted, the scope of work for engineers working for the District will be modified to include water quality data.

Legal Aspects of Urban Storm Water Management and related Pollution Abatement Problems

by Frank E. Maloney[*]

I - Introduction

The proper management of storm water runoff is a problem of tionwide significance which is just now beginning to be given he attention by urban planners that it has long deserved. The solution to this problem seems to be two-fold -- more and larger storm sewers for the paved areas, and temporary storm water detention in higher lands to allow the storm drains to perform their function without overflowing. These solutions in themselves present numerous legal problems, not the least of which is finding legal means to provide the funds for their accomplishment.

But another problem has been added -- one that the turn of the century planners who provided many of the now inadequate storm sewers never had to consider. That problem is the pollution created by storm water runoff, and the proscription of such pollution in the Federal Water Pollution Act and its state counterparts. This problem is of course exacerbated in those urban areas where ancient storm sewers double as sanitary sewers, with the sanitary sewer effluent by-passing the local treatment plant whenever the storm water runoff exceeds the capacity of the plant, normally after every hard rain.

---

[*] B.A. 1939, University of Toronto; J.D. 1942, University of Florida; Professor of Law and Dean Emeritus, University of Florida Law Center, Dean 1958-1970; Principal Investigator, Water Resources Scientific Information Center of Competence in Eastern Water Law.

But even without the sanitary effluent problem, the storm waters themselves collect their own pollutants from the city streets and other paved areas, and it would seem that the zero population goal of the 1972 amendments to the FWPCA cannot be achieved without somehow solving the problem of pollution in storm water runoff.

This paper will examine these two problems separately. It will first address the problem of providing for the disposal of the water itself, at the same time examining the "taking" issue inevitably associated with that problem. The second part of the paper will attempt an analysis of some of the legal ramifications of the associated pollution problem which it is now realized is equally as difficult of solution as the disposal problem itself.

II. The Disposal Problem

Leaving aside for the moment the pollution control problem, there are basically two approaches to storm water disposal, though both are inescapably interrelated. The first is to detain the storm water for a period, allowing at least a part of it to percolate underground and join the ground water resources of the area, while delaying the runoff of the rest long enough so that existing drains can handle it without becoming so overtaxed as to cause other problems. The second approach, often necessary even if the first is also undertaken, is to improve the carrying capacity of the drains over lower lands to avoid flooding from the increased water flows.

A. Increasing the flow over lower lands. It may be appropriate to examine the second procedure first. Assuming the engineering problems involved in increasing the flow are manageable, there still may be serious legal problems concerning the right to increase the flow, whether through natural surface drainways or by artificial pipes which eventually empty into a natural surface drain or stream.

Two basic doctrines are employed in determining the legality of upper owners, including municipalities, draining their lands over those of adjoining lower owners, as contrasted with the possible right of the lower owner to turn the draining surface waters back upon his neighbor. They are the civil law rule[1] and the common enemy doctrine.[2]

The civil law rule is expressed in the maxim *Aqua currit et debet currere, ut currere solebat*.[3] ("Water runs and should run, as it is wont to do"). The rule in its purest form is that no man may interfere with the natural flow of surface waters. It is usually expressed in terms of an easement of natural drainage as between adjoining lands, so that the lower owner must accept the surface water which naturally drains onto his land, but the upper owner can do nothing to increase that burden.[4] The rule is a part of the common law of England[5] and dates back to the Roman Law and the Code Napoleon.[6]

The advantage of the civil law rule is that rights thereunder are readily predictable, but strictly applied it tends to inhibit development and improvement of land,[7] and courts have frequently modified it when asked to apply it to purely urban conditions. The rule is almost universally interpreted to allow the upper owner to enhance the drainage of his property to some degree. The upper owner is generally allowed to hasten the flow of water by improving the natural drainage.[8] The degree to which he is allowed to artificially drain his upper estate has been limited by the requirement that he not act unreasonably or negligently;[9] by a balancing of relative benefit and harm;[10] by the condition that the increase in flow not be substantial or material;[11] by a prudent regard for the welfare of his neighbor;[12] and by the requirement that the waters not be diverted from their natural flow and concentrated so as to flow onto the lower lands at a different point.[13] On the other hand, the upper owner is sometimes allowed to greatly increase the flow of water by a simple finding that the drainage channel by which the water leaves his land is a "natural watercourse".[14]

While the lower owner is forbidden by the rule to obstruct the "natural" flow of surface waters, his burden may be eased by finding that the flow obstructed is not natural, in that it has been artificially created or enhanced by another.[15] Other courts have allowed the lower owner to obstruct surface water as long as he does not act negligently.[16]

As a result of these modifications, the general civil law rule today is that the upper owner may improve and enhance the natural drainage of his land as long as he acts reasonably and does not divert the flow, and that the lower owner is subject to an easement for such flow as the upper owner is allowed to cast upon him. Any obstruction of this flow by the lower owner or diversion by the upper owner is generally forbidden, but may be allowed in some jurisdictions subject to the limitation of reasonableness. On the other hand, an upper urban proprietor is generally prohibited from concentrating water in artificial channels and discharging it on on his neighbor to his harm.[17] This rule has been applied to subdividers of upper property in a number of cases.[18]

The common enemy rule, followed in New England[19] and a number of the Northeastern states,[20] and by South Carolina in the Southeast,[21] in its pure form would give each landowner the right to deal as he pleases with surface water on his land without regard for the consequences to his neighbor. The doctrine originated in the right of a property owner to use his own property as he pleases,[22] but has been justified on the basis of the right to fight the "common enemy",[23] and on the ground that it encourages land improvement and cultivation.[24]

Taken literally, the common enemy rule means that the upper owner may drain or divert the flow of surface waters onto the land of his neighbor at will, and that the lower owner is free to obstruct the water as he pleases and back it up onto the upper owner again. The rule has the advantage of simplicity, and since there can be no invasion of one another's legal rights, litigation should be minimized. On the other hand, landowners are encouraged to engage in contests of hydraulic engineering in which "might makes right" and breach of the peace is often inevitable. Fortunately, the rigors of the common enemy rule has led the courts adopting it to affix qualifications to meet the various situations arising.

As in the case of the civil law rule, a number of modifications have taken place in the application of the rule. For example in Sheehan v. Flynn[25] the Minnesota Court announced that even under the common enemy rule it is the duty of an owner draining his land to deposit surface water in some natural waterbody, if one is reasonably accessible. In another case applying the common enemy rule, the Missouri Court held a landowner was not justified in improving his own property so as to interfere seriously with adjacent properties.[26] The modern common enemy rule can be said to give the landowner the right to obstruct or divert surface water only so long as such obstruction or diversion is incident to ordinary use, improvement, or protection of his land, and is done without malice or negligence.[27]

The rule of reasonable use occupies the middle ground between the common enemy and civil law rules in their extreme forms and produces results similar to the modified versions of both. The advantage of the rule is that it embodies tort principles and disregards the cumbersome property notions of servitude and absolute ownership, but since the question of reasonableness is regarded as a mixed question of law and fact for the jury,[28] much of the predictability embodied in the other rules is lost.

The doctrine of reasonable use was first applied in New Hampshire,[29] and has since been expressly adopted by New Jersey,[30] Minnesota,[31] and Alaska.[32] Other states, without expressly adopting the rule, have reached practically the same results through modification of the traditional rules. The Maryland courts, for example, follow the civil law rule, but Maryland's equity courts apply the doctrine of reasonable use when it appears that undue hardship will result from the civil law rule.[33]

Although the courts have treated the doctrine of reasonable use as a separate rule on equal footing with the civil law and common enemy rules, it is in reality merely the general tort principle which would decide such cases in the absence of the application of either of the two "property" rules.

Most surface water cases involve acts of an upper owner which cause water to flow in increased quantity or a different manner onto the land of the lower owner, to his injury. The abundance of such cases is ready proof of the inadequacy of the traditional rules, for under the strict common enemy rule the lower owner would have no cause of action, while under the strict civil law rule the upper owner would have no defense, and with such predictable results litigation would be infrequent. The courts have been repeatedly called upon, however, to determine to what extent and in what situations the various modifications to both rules apply.

As a general rule a landowner may improve the drainage of his property so long as he merely enhances the natural flow of surface waters, but he may not divert surface waters from their natural path nor may he collect them into a body and discharge them onto the lower land.

B. Drainage into a Natural Watercourse. The right to drain surface water into a natural watercourse requires further treatment. The general rule is that a riparian owner may drain surface waters into a natural watercourse regardless of whether the civil law or common enemy rule is followed. This right is subject to at least three limitations which may be applied singly or in combination in various jurisdictions. These limitations are:[34] (1) the drainage must be reasonable; (2) waters must not be drained into a watercourse which would not have found their way there naturally; and (3) the natural capacity of the stream must not be exceeded.

C. Theories of Action and Legal Remedies. When surface waters, including storm waters, illegally invade another's property, liability may be based on theories of trespass, nuisance, or negligence. At common law, every unauthorized entry upon the soil of another is a trespass,[35] and the trespass action is sometimes used as the theoretical basis for relief for such invasions. However, the preponderance of modern cases treat surface water interference on the theory of private nuisance.[36] Nuisance has traditionally been defined as an unlawful act which causes injury to a person in the enjoyment of his estate, unaccompanied by an actual invasion of the property itself,[37] this latter distinction is frequently disregarded today.[38] In order for a surface water case to fit this definition, attention must be focused on the defendant's act as the nuisance and not the resulting overflow which actually invades the plaintiff's property. If emphasis is placed on the overflow of the property, then the theory of trespass may appear more appropriate. When defendant creates a condition which threatens imminent overflow, the plaintiff may be successful in abating the condition as a nuisance, while he might be required to wait for actual injury if he sued in trespass or negligence.

Negligence is the only theory available in some common enemy jurisdictions where acts of interference with surface water are actionable only if negligently done.[39] A negligence action has the advantage that it does not usually accrue, and thus the statute of limitations does not begin to run, until actual harm is done.[40] But there is the disadvantage that the plaintiff's action may be defeated by his own contributory negligence.

The preferred type of relief against wrongful interference with surface water is the injunction. This is because injunctive relief is preventive and can furnish relief before rather than after a threatened violation. Moreover, an injunction may in many cases be the only effective sanction because provable injury may be so small that a judgment for damages would be valuable only as a means of preventing the gaining of a prescriptive right by the defendant.

An injunction will ordinarily issue only if the plaintiff establishes facts that would entitle him to that relief according to the traditional equity rules governing issuance of injunctions. Thus, the plaintiff must show, not only that the defendant's act is unlawful, but also that the threatened injury is irreparable, or one that cannot be adequately compensated by an action at law, or that an injunction is necessary to prevent a multiplicity of suits at law.[41] Although these facts are undoubtedly prerequisites, in theory at least, for an injunction against interference with surface waters, they are rarely considered in direct terms by modern courts. Instead, it seems clear from the cases that any actionable interference with surface waters will give rise to an injunction if the plaintiff can show a definite threat of substantial continuous or future injury.[42] The reason for this liberal treatment of persons injured by surface waters is the unique nature of real estate. Damages for its invasion by surface waters will nearly always be an inadequate remedy, and to force the person injured to give up some of his rights or ownership in return for damages confers a power of eminent domain on the wrongdoer. However, in cases in which the public benefit from the continuance of the nuisance outweighs the harm to the injured party, the injunction may be denied by some courts as a matter of discretion under the balance of convenience doctrine.[43] The fact that the defendant is a municipality or other public body is not necessarily controlling,[44] but it may be an extremely important factor in weighing the balance against injunctive relief, in which case the court may leave the aggrieved complainant to his remedy by way of damages.[45] A municipality should not rely on such a result, however, since it is within the power of the court to grant the injunction, and injunctive relief has been granted in a number of such cases.[46]

How does all of this apply with respect to potential municipal liability? As a general proposition, it has been stated that municipalities are not liable for mere failure to provide drainage systems, a type of municipal nonfeasance.[47] They have likewise been excepted from negligence in planning for disposal of storm waters on the basis that such planning is a discretionary function.[48] As one commentator has pointed out, this favorable treatment in negligence actions against local government units ironically may be at the root of municipal failure to build storm water drainage systems.[49] Negligence in construction, as distinguished from design, may be another matter. The extent to which a particular state has waived municipal governmental immunity may be controlling here, and in some jurisdictions the classification of the drainage work as governmental or proprietary may be determinative.[50]

In any event, if the result of the municipality's acts is to cast additional waters on the complainant's land, the city may well be liable on the basis of the common law authorities previously discussed.[51] Such liability could result not only from harm done by the waters themselves, but also from illegal alterations in surface water courses resulting in harm to lower riparian owners.[52]

What if a storm sewer which is originally adequate becomes overtaxed as a result of additional development on higher lands? Again, the cases are split, with a number of courts imposing a duty on the municipality to correct the inadequacy,[53] but others refusing to assess liability for the inadequate performance of a governmental function.[54]

If drainage works or changes in established grades by a municipality result in flooding of lower property owners, one way in which such owners may avoid a defense of governmental immunity where that defense is still available is through theories of inverse condemnation on the theory that the city has taken private property or at least a flood easement in such property by its action.[55] Theories of nuisance have also been applied to avoid a defense of governmental immunity in some jurisdictions.[56]

III. THE STORM WATER DETENTION PROBLEM

As stated earlier, one part of the solution to the storm water problem is temporary detention of the water on higher lands to prevent overloading lower drains. But if this approach is implemented through legislation providing for flood plain zoning, mandatory retention of runoff, or other land use regulations, certain constitutional challenges may result in the invalidation of these regulatory measures. Depending upon the particular piece of property involved, a landowner may validly contend that a deprivation of property rights has occurred as a result of the regulation questioned.

The concept of "taking" originally referred to the outright seizure of the land by the government. This meaning appears to be that contemplated at the time the concept was incorporated into our Constitution.[57] This original conception of the taking of property by government appears to have given rise to two separate rules regarding governmental powers over land that has persisted well into this century: government, on the one hand, had a duty to pay compensation if land was seized for public use, and on the other hand, government had a right to regulate the use of land so long as the regulation was reasonably related to a public purpose.

The separation between a taking and mere regulation had its hey-day at the end of the last century. In 1887 the United States Supreme Court declared the then accepted law with respect to regulation and taking:

> A prohibition simply upon the use of property for purposes that are declared by valid legislation to be injurious to the health, morals or safety of the community cannot in any just sense be deemed a taking or appropriation of property for the public benefit. Such legislation does not disturb the owner in the control or use of his property for lawful purposes nor restrict his right to dispose of it, but it is only a declaration by the state that its use by anyone for certain forbidden purposes is prejudicial to the public interest.[58]

About 35 years later, the Supreme Court decided the case of Pennsylvania v. Mahon,[59] which today is seen as a landmark case in the shift of legal theory that has now linked the once separate theories of "taking" and "regulation."

Speaking for the court, Justice Holmes noted the general rule "... that while property may be regulated to a certain extent, if regulation goes too far it will be recognized as a taking."[60] In order to measure the permissible scope of regulation, the court established the "diminution of value test" stating:

> One fact for consideration in determining such limits is the extent of the diminution. When it reaches a certain magnitude in most if not all cases there must be an exercise of eminent domain and compensation to sustain the act.[61]

Although the magnitude of diminution necessary to constitute a taking is not clear, if the market value of the property is completely destroyed, one would expect that the requisite magnitude has been reached. However, the law has now developed so that property owners will not be compensated for regulations that prevent the highest and best use that one can make of their property as long as the property can be put to a reasonable use.[62] Generally, the diminution of value test has played a decreasing role in state court decisions and is now only one of several factors to be considered in determining the validity of a regulation. It now appears that courts to a larger degree engage in a balancing of the public interest, comparing the need for the regulation with the degree of infringement of property rights.[63] Over the last fifty years state courts have decided literally hundreds of cases, each of which determines whether the value of a particular land use regulation does or does not outweigh the loss of property value to a particular landowner. These decisions are nothing short of chaotic. Numerous tests have been established to determine whether certain regulations are so extreme as to constitute an unconstitutional taking. Although the courts have an array of theories to draw from when faced with a taking issue, a sizeable minority are shifting to the "newer" approaches which allow local governments greater lattitude in adopting regulations.[64]

In planning control measures such as the location of retention basins, it is conceivable that the only feasible location would be in such a place that the development value of the property might be substantially reduced. This would especially be a problem with smaller intensive developments where the amount of land required for the retention basin is proportionally greater when compared to that actually developed for resale. However, new engineering and planning techniques may alleviate this problem. Despite such possibilities, a property owner may still argue that the value of the land actually set aside for the basin has been taken since it cannot be used, particularly if it must be left in its natural state, without obstruction or occupation. If the retention basin were of considerable size, its value as development property would be greater and thus the loss to the landowner greater also.

In some cases it may be argued that what is really taken is the property right of naturally draining one's property, which is arguably a taking if it goes to the extent of seriously interfering with reasonable use of the property.[65]

Generally, the taking question revolves around vague principles of law which seek to balance private property rights against the public good. Each case will depend upon its particular facts. Storm water management planners should always take into consideration the effect of their plans on regulation of private property in light of the taking question. Obviously this is not to say that detention on upper lands is always a taking. In all probability it can most often be classed as justifiable regulation in the public interest. Thus the city of Gainesville, Florida has recently enacted a flood plain zoning ordinance which while yet untested legally, is a scientifically sound regulatory approach to the problem which is worth further study as a model for such regulation. Subdivision regulations, building and housing codes, and reservation of low lying areas for parks and recreational facilities are other possibilities to help protect urban areas against flooding.

IV. The Pollution Problem

Let us now turn to the second major problem respecting urban storm water management -- that of pollution control.

A. Common Law Development

As in the first part of this paper it may be appropriate to begin an analysis of the problem with a discussion of the common law legal remedies and their current status in the law of pollution control today. In the past, such remedies frequently failed to adequately protect the public interest. This failure has been a contributing factor in legislative attempts to provide greater environmental protection. Inadequacies of earlier pollution control legislation, in turn, have led a number of courts to reexamine and sometimes refurbish the common-law remedies.[66]

Examining these remedies, one finds a blend of property and tort law governing them. The first such remedy stems from a property law concept rooted in Eastern riparian water law doctrine. The riparian owner, according to the older natural flow doctrine, has no right to change the natural condition or characteristics of the water in a navigable water body, and any such change is actionable without the necessity of actual harm.[67] This rule remains in effect in a few Eastern jurisdictions including Georgia and South Carolina.[68] In most Eastern states, however, the reasonable use rule modifies the strict approach of natural flow and grants the lower riparian only the right to have his water kept free from unreasonable interference.[69] A use cannot be unreasonable if there is no actual injury to other riparian owners.[70]

Even if there is injury, the use nevertheless may be privileged if reasonable under all the facts.[71] Thus, in certain circumstances the pollution of water may be reasonable and therefore lawful under the latter approach.[72]

Reasonableness is a factual question controlled by the circumstances of each case. It cannot be determined in advance with any certainty.[73] In deciding how much pollution is reasonable courts have considered these factors: the stream's character, its volume and velocity, past uses of the stream, location and use of the plaintiff's land, extent of plaintiff's damages, local customs and customs of the industry involved, and comparative public concern on the two sides of the controversy.[74]

The switch from the natural flow to the reasonable use rule robbed the water law property concept of much of its effectiveness as a tool for pollution control. As a result, today the usual theory of action in a pollution suit is private nuisance. As is the case in the disposal problems discussed earlier, the nuisance suit is predicated upon an unreasonable interference with the use and enjoyment of land and accompanying water rights.[75] Trespass is another theory employed by some courts,[76] but it is not often relied upon since it is considered possessory in nature.

Considering the nuisance remedy in more detail, private nuisance is an unreasonable interference with the use and enjoyment of real property, and obtaining relief is dependent upon both proof of damage and a finding that the defendant's activities are "unreasonable".[77] A public nuisance action, on the other hand, is available for injury to the public in the exercise of its common rights.[78] The activity that constitutes a public nuisance is usually a crime, but the existence of criminal sanctions generally does not make the tort remedy unavailable.[79] If an act interferes both with common rights of the public and with private use and enjoyment of land, a private as well as public nuisance action may be available, but a private individual may not maintain the public nuisance action in the absence of proof of special damage to him different in kind from that suffered by the public at large. Absent such special damage, the state, as protector of the public, is the proper plaintiff.[80]

The preferred relief against both public and private nuisances is the injunction because it furnishes a remedy before rather than after damage occurs. Moreover, in many cases injunctive relief may be the only effective sanction because provable injury to any one individual is so small that a judgment for damages would be valuable only to prevent the defendant from gaining a prescriptive right. An injunction, however, will be issued only if the plaintiff proves that injunctive relief is necessary because the threatened injury is irreparable. This would be the case if the injury could not be adequately compensated for by damages at law, or if a multiplicity of suits would result from failure to grant the injunction.[81]

As pointed out in Part II of this paper, an injunction may be refused for several reasons. In comparing the relative importance of the interests of the parties to determine whether to grant injunctive relief, or "balancing the equities," a court may deny an injunction on the ground that the public interest in permitting a particular activity to continue is of overriding importance despite damage to the plaintiff.[82] This defense is often raised on behalf of municipal or governmental operations,[83] and has been relatively successful in earlier cases. Another roadblock, at least against the prosecution of a public nuisance action, may be a claim that the state, either by legislative action or by constitutional amendment, has legalized a type of pollution, thereby lifting it out of the category of a public nuisance.[84] Thus, an ordinance authorizing storm sewers arguably could be construed as taking the pollution of streams by storm water discharges out of the public nuisance category.[85]

With respect to both public and private nuisance, until recent years courts in general tended to overprotect the right to own and use private property and failed to recognize the ecological consequences of pollution.[86] This led them, for the most part, either to deny the existence of the nuisance altogether, or to refuse an injunction because the economic importance of the polluter's operations caused the equities to be balanced in favor of the polluter.[87]

In the absence of the effective statutory regulation, conservationists increasingly fell back on private lawsuits during the 1960's in their attempts to protect the environment. They have been successful in a number of recent cases in which some courts appear to have reversed their traditional bias favoring exploiters of the environment. Today, emphasis on the factor of danger to public health is beginning to tip the scales in favor of injunctive relief where balanced against economic interests.[88] Moreover, where courts once considered only the interests of the immediate parties to the lawsuit, they are now beginning to respond to societal as well as the private issues involved. This new awareness, of course, may cut both ways when injunctive relief against a municipality is being sought, but planners of storm water drainage facilities need to be aware of the possibility that those receiving polluted storm waters have a better chance today than in the past of obtaining both damages and injunctive relief in common law actions. It is still true, however, that generally, common law tort liability has been an ineffective technique for controlling pollution.[89] For this, among other reasons, both state and federal legislatures, have placed pollution control primarily in the hands of administrative agencies.[90]

B. Water Pollution Legislation

1. General Validity

Although the present environmental consciousness was slow to bloom, anti-water pollution legislation is not a recent innovation. For many years the courts of numerous jurisdictions have construed and passed upon the validity of such measures. Generally the courts have held that anti-water pollution legislation is a valid exercise of the police power to protect the public health and welfare. Such statutes, administrative regulations and ordinances have been upheld against allegations that they are unreasonable, illegally promulgated, and constitute an unconstitutional taking of property without compensation. Very few cases have invalidated anti-water pollution efforts, and those that have, were mostly earlier cases (pre-1930).[91]

2. FWPCA Amendments 1972

(a) Goals

With the enactment of the 1972 Federal Water Pollution Control Act Amendments (FWPCA), the federal government has taken over a prominent role in water pollution control. Section 101 (a) of the Act makes the restoration and maintenance of the chemical, physical, and biological integrity of the nation's waters a national goal.[92] This is to be accomplished by: (1) eliminating the discharge of pollutants into navigable waters by 1985; (2) attaining a degree of water quality conducive to recreation and the protection of fish and wildlife by July 1, 1983; (3) forbidding the discharge of toxic pollutants; (4) constructing publicly owned treatment works through Federal financial assistance; (5) implementing areawide waste treatment management plans; and (6) initiating research to develop the necessary technology.[93]

Water quality standards established by the 1972 FWPCA Amendments do not depend upon the quality of the body of water receiving the discharges, but emphasize treatment at the pollution sources.[94] As one commentator put it, "This change from 'receiving water standard's to effluent limitation standards' is new to the field of water pollution control, and is the principal reason for the widespread controversy about the 1972 Amendments."[95] Other commentators suggest that the goals may not be realized within the statutory deadline, because of high costs involved in attaining the zero discharge goal, and this factor is particularly true of the treatment of storm water runoff. The Act has been criticized as requiring wastewater treatment beyond what is necessary to preserve the nation's water resources, and creating costs which greatly exceed the social benefit. Some writers suggest that Congress must revise the statutory timetables if the Act is to remain an effective measure. It remains to be seen whether this suggestion will be acted upon, but meanwhile the zero discharge goal appears to have set an almost impossible task for those concerned with disposal of urban storm water runoff.

(b) Enforcement & Citizen Suits

The enforcement provisions of the FWPCA Act should be considered in light of the awesome task it requires. Previous legislation rarely contained provisions for enforcement actions against municipal polluters.[96] Today, Section 502 (5) of the Act indicates that the enforcement provisions apply to municipalities. This result is accomplished by defining person as "... an individual, corporation, partnership, association, state, municipality, commission, or political subdivision of a state, or any interstate body". Because some state laws make local financing of treatment plants extremely difficult, cities may find themselves confronted with enforcement actions involving fines and mandatory court orders. Without the financial tools to make compliance realistically possible, quite a dilemma exists for some local governments.

However, it is interesting to note that Section 309 (e) added by the 1972 Amendments requires joinder of the state as a party in civil actions instituted by the United States against a municipality.[97] This section provides that the "...State shall be liable for payment of any judgment, or any expense incurred as a result of complying with any judgment entered against the municipality in such action to the extent that the laws of the state prevent the municipality from raising revenues needed to comply with such judgment." This section appears to serve as an inducement for the states to lessen constraints on municipalities.

An important provision relevant to federal enforcement, §505, gives citizens the right to seek court enforcement of effluent limitations and standards.[98] The authorization includes suits against the EPA for failure to perform non-discretionary duties.[99] This section acquires significance in relation to enforcement provisions which require the EPA to take action against polluters. Further, it is interesting to observe that federal court jurisdiction is without regard to the amount in controversy,[100] and that subsequent cases have held that the FWPCA Amendments do not abrogate the common law remedies discussed previously.[101]

(c) Point and Nonpoint Sources

In establishing effluent discharge limitations the 1972 FWPCA Amendments distinguish point sources from nonpoint sources of pollution.[102] Section 502 (14) defines "point source" as "...any discernable, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged." In contrast with point source, non-point source is not directly defined in the Act. A reading of Section 304 (c), however, indicates such sources as run-off from fields, construction sites, and mines, along with seepage of various sorts not flowing from "discrete fissures" are all included in non-point sources.[103]

Interjection of storm water management into this framework poses some confusion, because storm water flow sometimes appears to fall into both point and non-point categories. Thus, in one sense, connection system flows may be considered as point pollution sources whereas sheet-flow runoff is termed as non-point pollution simply because it is not collected or directed in a defined pattern and may enter the receiving water at numerous locations. Arguably, storm water discharges may fall under the waste water effluent standards when categorized as point sources, and remedial action to include some form of treatment may be mandated under the Act. Since non-point sources and point sources are afforded somewhat different treatment by the Act, the statutory constraints on storm water disposal may vary with the disposal method used. However, the Act is new and complex thus, its definitions, limitations, and requirements have not, as yet, been interpreted with the utmost of clarity.[104]

(d) Navigable Waters

A very crucial, yet unanswered question, is the extent of federal jurisdiction under the Act. Generally, federal power over inland waters has been associated with the "navigable waters" formula, and the 1972 Amendments to the FWPCA also seem to tie jurisdiction to navigable waters. However, the 1972 Act defines "navigable waters" as "...the waters of the United States including the territorial seas," §502 (7). Some commentators argue that federal jurisdiction does not extend to all the waters of the United States.[105] These arguments are supported somewhat by both the Constitution and established judicial precedent.[106] The Constitution does not directly empower Congress to regulate the waters of the United States. Federal jurisdiction over waterways has been implied from the Commerce Clause.[107] Regulation of navigable waters was thought to be implicit in the regulation of Commerce.

Some critics at first felt that the term "navigable waters" was a major loophole in the Act because discharges into non-navigable waters would not be regulated.[108] Earlier case law had held that federal jurisdiction is limited to navigable waters, but in two recent cases -- U.S. v. Ashland Oil Co.[109] and U.S. v. Holland[110] -- FWPCA jurisdiction has been held to extend to non-navigable waters. Administrative definitions seek to give the term "navigable waters" its "broadest possible constitutional interpretation."[111] Confusion arises from the fact that while Congress defined "navigable waters" as "waters of the United States", it failed to define "waters of the United States", thus leaving open to question whether federal jurisdiction under the Act remains bound to "navigable waters".[112]

An additional problem is whether the FWPCA Amendments apply to discharge of pollutants into subsurface waters. This problem is of great relevance in states such as Florida where underground injection of wastes is a fairly common occurrence. Two federal district courts, in Texas and Arizona, have spoken to this issue, with a resulting split of authority.[113]

Because of the confusion over jurisdiction under the FWPCA 1972 Amendments, some commentators suggest that Congress should avoid reliance on the Commerce Clause and exercise federal power under the General Welfare Clause. However, under the Welfare Clause the costs may be greater, because the courts have often found regulation under that clause to be a compensable taking of property, while Congress has been given greater license under the Commerce Clause.[114] Yet, with today's increased public awareness of environmental conservation, and an increased judicial affinity for environmental legislation, arguably federal water pollution jurisdiction may be justified adequately under either constitutional provision.

V. CONCLUSION

Continuing rapid urbanization in the United States has brought the storm water runoff problem to the forefront of the consciousness of many urban planners who have come to the realization that urban growth normally results in a radical alteration of the natural drainage patterns of the urbanized area, and that a properly planned storm water drainage system has become a necessity from both a practical and legal viewpoint.

In general, municipalities today have the legislative authority to plan for and establish such systems. Additional legislation to provide for more adequate funding, including possible user charges to be assessed against those from whose land the discharges originate, may well be necessary to fully implement such plans. In this connection, provisions for regional planning and implementation should not be overlooked.

The primary disincentive is one of costs--costs not only for acquisition of rights of way and flood easements to avoid potential lawsuits by lower owners who are injured by increased water flows, but also, under new state and federal anti-pollution laws, for what could be staggering costs to attain zero pollution in the extremely large discharges of storm water runoff into the waters of the nation.

The problem of avoiding excessive and over-rapid discharges can be solved in part by provision for detention and temporary storage of more storm water on upper lands. The possibility that requiring such detention constitutes a taking of property rights of upper landowners for which compensation must be paid is a disincentive to this type of planning.

However, reasonable flood plain zoning, now mandated for many communities by a strong Federal Flood Insurance Act,[115] should help keep the cost of providing for such detention within reasonable parameters, even if flood easements have to be purchased or condemned by the community.

The anti-pollution problem may be more difficult of solution. If the zero pollution goal of the FWPCA is to be applied to storm water runoff in the same way as to pollution from sanitary facilities, without new technological breakthroughs in treatment methodology, massive costs will necessarily be involved. It would seem reasonable that the federal government, which has mandated the treatment, should bear at least a major portion of those costs. Whether the Congress of the United States will face up to this obligation, or alternatively provide some lesser purity requirement for storm water runoff, remains to be seen.

Storm water detention, with resulting discharge of a part of the polluted water into the groundwater system, will alleviate the problem somewhat insofar as discharges into surface waters are concerned, but if the courts agree that the waters of the United States include groundwaters, any effort to avoid the pollution problem through discharge into groundwater aquifers will eventually prove non-productive. Enforcement agencies probably will not be allowed to ignore the problem as it disappears into the ground. The citizen suit provisions of the FWPCA plus possible use of the common-law legal remedies may well assure that the problem will be faced up to through litigation in the courts. The ultimate solution to this problem may prove to be a technological rather than a legal one. Absent any amendment of the existing law, however, one can look forward to some interesting litigation in the 1980's.

Footnotes

1. *See, e.g.*, Tiedeman v. Village of Middleton, 25 Wis. 2d 443, 130 N.W.2d 783 (1964); Phillips v. Chesson, 281 N.C. 566, 58 S.E.2d 343 (1950); Slatten v. Mitchell, 22 Tenn. App. 547, 124 S.W.2d 310 (1938); Note, *California's Surface Waters*, 39 *So. Cal. L. Rev*. 128 (1966).

2. *See, e.g.*, Turner v. Smith, 217 Ark. 441, 231 S.W.2d 110 (1950); Tide Water Oil Sales Corp. v. Shimelman, 114 Conn. 182, 158 A.229 (1932); Bennett v. Cupina, 253 N.Y. 436, 171 N.E. 698 (1930); Davis, *The Law of Surface Water in Missouri*, 24 *Mo. L. Rev*. 137 (1959).

3. *Kent, Commentaries on American Law* 439 (14th ed. 1896); Kauffman v. Griesemer, 26 Pa. 407, 413 (1856).

4. Gough v. Goble, 2 Ill. 2d 577, 119 N.E.2d 252 (1954); *see* Annot., 59 A.L.R.2d 421, 429 (1958).

5. 3 *Farnham*, *Waters & Water Rights* §877 (1904); the modern English law of drainage is largely statutory; *see* *Coulson & Forbes*, *Law of Waters*, 823-37 (6th ed. 1952).

6. 3 *Farnham*, note 5, *supra*, at §889a.

7. The present provisions of the Louisiana Civil Code express the civil law position: "It is a servitude due by the estate situated below to receive the waters which run naturally from the estate situated above, provided the industry of man has not been used to create that servitude.
   "The proprietor below is not at liberty to raise any dam or to make any other work, to prevent this running of the water.
   "The proprietor above can do nothing whereby the natural servitude due by the estate below may be rendered more burdensome." *La. Stat. Ann.*, *Civ. Code*, *Art*. 660 (1972).

8. *E.g.*, La Fleur v. Kolda, 71 S.D. 162, 22 N.W.2d 741 (1946).

9. *E.g.*, Ratcliffe, v. Indian Hill Acres, Inc., 93 Ohio App. 231, 113 N.E.2d 30 (1952); Thompson v. Andrews, 39 S.D. 477, 165 N.W. 9 (1917).

10. *E.g.*, Venson v. Turner, 252 Ala. 271, 40 So.2d 863 (1949); Battisto v. Perkins, 210 Md. 542, 124 A.2d 288 (1956).

11. *E.g.*, Cundiff v. Kopseiber, 245 Iowa 179, 61 N.W.2d 443 (1953); Bishop v. Richard, 193 Md. 6, 65 A.2d 334 (1949).

12. *E.g.*, Hughes v. Anderson, 68 Ala. 280 (1880).

13. *E.g.*, Martin v. Jett, 12 La. 501 (1838).

14. *See* Annot., 81 A.L.R. 262 (1932).

15. *See* F. Maloney, S. Plager & F. Baldwin, *Water Law and Administration, The Florida Experience* §75 (1968).

16. Taylor v. Harrison Constr. Co., 178 Pa. Super. 544, 115 A.2d 757 (1955).

17. Kay-Noojan Dev. Co. v. Kinzer, 259 Ala. 49, 65 So.2d 510 (1953).

18. *E.g.*, Rau v. Wilden Acres, Inc., 376 Pa. 493, 103 A.2d 422 (1954).

19. Tide Water Oil Sales Corp. v. Shimelman, 114 Conn. 182, 158 A. 229 (1932); Greely v. Maine Cent. R. Co., 53 Me. 200 (1865); Harrison v. Poli-New England Theatres, Inc. 304 Mass. 123, 23 N.E.2d 99 (1939).

20. E.g., Bennett v. Cupina, 253 N.Y. 436, 171 N.E. 698 (1930); Nassau County v. Cherry Valley Estates, Inc., 281 App. Div. 692, 117 N.Y.S.2d 616 (1952).

21. *See* Deason v. Southern R. Co., 142 S.C. 328, 140 S.E. 575 (1927).

22. Gannon v. Hargadon, 92 Mass. 106 (1865), citing the maxim "Cujust est solum, ejus est usque ad coelum."

23. Town of Union v. Durkes, 38 N.J.L. 21 (1875).

24. *E.g.*, Timmons v. Clayton, 222 Ark. 327, 259 S.W.2d 501 (1953); Borkley v. Wilcop, 86 N.Y. 140 (1887); Bowlsby v. Speer, 31 N.J.L. 351 (1865).

25. 59 Minn. 436, 61 N.Y. 462 (1894).

26. Frendenstein v. Heine, 6 Mo. App. 287 (Ct. App. 1878).

27. *See* Dobbins, *Surface Water Drainage*, 36 *Notre Dame Law*, 518, 523-24 (1961).

28. Swett v. Cutts, 50 N.H. 439 (1870).

29. Franklin v. Durgee, 71 N.H. 186, 51 A. 911 (1901); Swett v. Cutts, 50 N.H. 439 (1870).

30. Hopler v. Morris Hills Regional Dist., 45 N.J. Super. 409, 133 A.2d 336 (Super. Ct. App. Div. 1957); Armstrong v. Francis Corp., 20 N.H. 320, 120 A.2d 4 (1956).

31. Enderson v. Kelehan, 226 Minn. 163, 32 N.W.2d 286 (1948); Sheehan v. Flynn, 59 Minn. 436, 61 N.W. 462 (1894).

32. Weinberg v. Northern Alaska Dev. Corp., 284 P.2d 450 (Alas. 1963).

33. Whitman v. Forney, 181 Md. 652, 31 A.2d 630 (1943); *see* Comment, 11 *Md. L. Rev.* 58 (1950).

34. These limitations are developed in more detail in the discussion of cases in the text following.

35. *See* *Prosser*, *Torts* §63 (4th ed. 1971).

36. *See, e.g.*, Lawrence v. Eastern Air Lines, 81 So.2d 632 (Fla. 1955); Deason v. Southern R. Co., 142 S.C. 328, 140 S.E. 575 (1927); Henry v. Ohio River R. Co., 40 W. Va. 234, 21 S.E. 863 (1895).

37. *Defuniak*, *Handbook of Modern Equity*, 59 (2d ed. 1956).

38. *See* Miami Springs v. Lawrence, 102 So.2d 143 (Fla. 1958).

39. Bussell v. McClellan, 155 Neb. 875, 54 N.W.2d 81 (1952); Timmons v. Clayton, 222 Ark. 327, 259 S.W.2d 501 (1953).

40. *See* *F. Maloney*, *supra* note 15, §74.3.

41. Koch v. Wick, 87 So.2d 47 (Fla. 1956) (plaintiff seeking injunction and damages against city in ground water case); Roughton v. Thiele Kaolin Co., 209 Ga. 577, 74 S.E.2d 844 (1953); *see generally* 56 *Am. Jur.* *Waters* §421 (1947).

42. New Homes of Pensacola, Inc. v. Mayne, 169 So.2d 345 (1st D.C.A. Fla. 1964); Hunt v. Smith, 238 Iowa 543, 28 N.W.2d 213 (1947); *see also* Mader v. Metenbrink, 159 Neb. 118, 65 N.W.2d 334 (1954); Dixon v. City of Nashville, 29 Tenn. App. 282, 203 S.W.2d 178 (1946).

43. Harris v. City of Lakeland, 141 Fla. 795, 193 So. 826 (1950); City of Lakeland v. Harris, 143 Fla. 761, 197 So. 470 (1940) (court used balance of convenience doctrine to refuse injunctive relief against city); Maloney, *The Balance of Convenience Doctrine in the Southeastern States, Particularly as Applied to Water*, 5 S.C.L.Q. 159 (1952).

44. Lawrence v. Eastern Air Lines, 81 So.2d 632 (Fla. 1955).

45. Lakeland v. Harris, 143 Fla. 761, 197 So. 470 (1940); *see* Maloney, *supra* note 43, at 166.

46. *See* Penn v. City of Lakeland, 109 So.2d 771 (2d D.C.A. Fla. 1959).

47. Kenworthy, *Urban Drainage: Aspects of Public and Private Liability*, July-August 1962 *Dicta* 197, 205 (1962).

48. Martinez v. Cohn, 56 N.M. 343, 244 P.2d 134 (1952).

49. Shoemaker, *An Engineering-Legal Solution to Urban Drainage Problems*, 34 *Denver L. J.* 381, 385 (1968).

50. True v. Mayor of Westpoint, 196 Md. 280, 76 A.2d 135 (1950); *see also* Note, *Assault On The Citadel: De-immunizing Municipal Corporations*, 4 *Suffolk U. L. Rev.* 832, 859-60 (1970)

51. *See pp*. 9-12 *supra*; see also Brown v. Sigourney, 164 Iowa 184, 145 N.W. 478 (1914).

52. *See* pp. 9-10 *supra*.

53. Denver v. Mason, 88 Colo. 294, 295 Pac. 788 (1931); *see* annot., 70 A.L.R. 1347 (1931).

54. Bratonja v. Milwaukee, 3 Wis. 2d 120, 87 N.W.2d 775 (1958) (on the basis of discovery).

55. Dallas County v. Dillard, 156 Ala. 354, 47 So. 135 (1908). Bd. of County Commrs. v. Allen, 69 Colo. 290, 194 P. 621 (1920); Nelson County v. Loving, 126 Va. 283, 101 S.E. 406 (1919).

56. City of Ada v. Camoy, 198 Okl. 206, 177 P.2d 89 (1974); Greer v. Lennox, 79 S.D. 28, 107 N.W.2d 337 (1971).

57. *See* Bosselman, *The Constitutional Rights of Landowners v. the Need to Control Growth and Protect Our Environment*. Remarks to the Florida Young Lawyers Convention, March 9, 1974, p. 3.

58. Mugler v. Kansas, 123 U.S. 623 (1887).

59. Pennsylvania Coal v. Mahon, 260 U.S. 410 (1922).

60. *Id*. at 415.

61. *Id*. at 413.

62. *See* Goldblatt v. Hempstead, 369 U.S. 590 (1962).

63. Binder, *Taking Versus Reasonable Regulations, A Reappraisal in light of Regional Planning and Wetlands*, 25 *U. Fla. L. Rev.* 1, 5 (1972).

64. *See generally*, *Bosselman, Callies and Banta*, *The Taking Issue*, pt. 3, (U.S. GPO, 1973).

65. *See*, Hillsborough County Environmental Protection Commission v. Franderson Properties, Inc. 283 So.2d 65 (2d D.C.A. Fla. 1973).

66. Maloney, *Judicial Protection of the Environment: A New Role for Common Law Remedies*, 25 *Van. L. Rev.* 145, 146 (1972).

67. *F. Maloney*, *supra* note 15 §112.1.

68. Raughton v. Thiele Kaoline Co., 209 Ga. 577, 74 S.E. 2d 844 (1953); Williams v. Haile, 85 S.C. 1, 66 S.E. 1057 (1910).

69. *F. Maloney*, *supra* note 15, §112.1.

70. *Id*.

71. *See* Parsons v. Tennessee Coal, Iron & R.R., 186 Ala. 84, 64 So. 59 (1914).

72. In an early case involving pollution of an underground stream, the Florida court accepted the reasonable use modification of the natural flow doctrine, noting: "The right to the benefit and advantage of the water flowing past one owner's land is subject to the similar rights of all the proprietors on the banks of the stream to the reasonable enjoyment of a natural bounty, and it is therefore only for an unauthorized and *unreasonable* use of a common benefit that one has just cause to complain." Tampa Waterworks Co. v. Cline, 37 Fla. 586, 595, 20 So.780, 782 (1896) (emphasis added).

73. *Restatement of Torts*, §582, comment b (1939).

74. *Powell*, *Real Property* 376 (1962); Note, *Purity & Utility: Diversity of Interest in River Pollution*, 84 *U. Pa. L. Rev.* 630, 637 (1936).

75. *Prosser*, *Torts* 622 (3d ed. 1964).

76. W. G. Duncan Coal Co. v. Jones, 254 S.W. 2d 720 (Ky. 1953).

77. Beckman v. Marshall, 85 So.2d 552 (Fla. 1956).

78. Maier v. City of Ketchikan, 403 P.2d 34, 38 (Alas. 1965).

79. People v. Truckee Lumber Co., 116 Cal. 397, 48 P. 374 (1897).

80. *See*, *e.g.*, J. H. Miles & Co. v. McLean Contracting Co., 180 F.2d 789 (4th Cir. 1950).

81. Holman v. Athens Empire Laundry Co., 149 Ga. 345, 100 S.E. 207 (1919).

82. Cohen v. City of Houston, 176 S.W. 809, 814 (Tex. Civ. App. 1915).

83. *See generally*, Maloney, *The Balance of Convenience Doctrine in the Southeastern States, Particularly as Applied to Water*, 5 *S.C.L.Q.* 159 (1952).

84. *See* Juergensmeyer, *Common Law Remedies and Protection of the Environment*, 6 *U.B.C.L. Rev.* 215 (1971); 25 *Texas L. Rev.* 96 (1946).

85. In 1930 Florida added a section to its state constitution providing a fifteen-year tax exemption to particular industries as an inducement for establishing plants in Florida. In the case of National Container Corp. v. State ex rel Stockton, 138 Fla. 32, 189 So. 4 (1939), the Florida Supreme Court held that this exemption necessarily granted the polluter immunity from public nuisance suits. Similar results were reached by the Florida court in subsequent cases involving the drilling of oil wells in tidal waters pursuant to an oil lease statute and the operation of an airport under a municipal ordinance. Brooks v. Patterson, 159 Fla. 263, 31 So.2d 472 (1947).

86. Richard's Appeal, 57 Pa. 105 (1868).

87. However, it should be noted that not all of the early cases treated the environment so harshly. *See* Georgia v. Tennessee Copper Co., 206 U.S. 230 (1907).

88. *See*, *e.g.*, Department of Health v. Owens-Corning Fiberglass Corp., 100 N.J. Super. 366, 242 A.2d 21 (1968).

89. Perhaps the primary weakness is that the damage remedy, which is much easier to obtain for stream pollution than the injunction, is not designed to prevent pollution initially but to afford relief retrospectively to parties injured. Pollution and its control involve complex technical problems which courts simply are not equipped to handle effectively. Even were a particular court to have the necessary expertise, it would be in no position to formulate a comprehensive pollution control program because it is compelled to act on a case-by-case basis. *See* *F. Maloney*, *supra* note 15, §112.4.

90. *Id*.

91. 32 A.L.R. 3d at 232.

92. Joelson & Fleischaker, *The Water Pollution Control Act*, 20 *Prac. Law*. 29, 30 (1974).

93. *Id*.

94. 10 *Gonzaga L. Rev.* 165, 167 (1974).

95. *Id*. at 168.

96. *See generally*, Shinn, *The Federal Grant Program to Aid Construction of Municipal Sewage Treatment Plants: A Survey of the 1972 FWPCA Amendments*, 48 *Tul. L. Rev.* 85, 103 (1973).

97. *Id*. at 104.

98. 33 U.S.C. §1365 (supp. 1975).

99. 33 U.S.C. §1365 (a)(2)(supp. 1975).

100. 33 U.S.C. §1365(a)(supp. 1975); *see also* 1973 *Wis. L. Rev.* 893, 902 (1973).

101. *See, e.g.*, Illinois v. City of Milwaukee, Wis., 406 U.S. 91 (1972); United States v. United States Steel, 356 F. Supp. 556 (N.D. Ill. 1973).

102. *Compare* 33 U.S.C. §1362(14)(supp. 1975), with 33 U.S.C. §1314(e) (supp. 1975).

103. Smith, *Highlights of the Federal Water Pollution Control Act of 1972*, 77 *Dick. L. Rev*. 459, 468 (1973).

104. *Id*. at 491.

105. *See* 19 *St. Louis U. L. J.* 208 (1974).

106. *U.S. Const*., Art. 1, §8.

107. *See, e.g.*, United States v. Appalachian Electric Power Co., 311 U.S. 377 (1940).

108. 19 *St. Louis U. L. J.* 208, 217 (1974).

109. 504 F.2d 137 (6th Cir. 1974).

110. 373 F. Supp. 665 (M.D. Fla. 1974).

111. In considering the term, the EPA issued this statement: "However, for the purpose of making initial administrative determinations, at least the following waters would appear to be 'waters of the United States':

(1) All navigable waters of the United States;
(2) Tributaries of navigable waters of the United States;
(3) Interstate waters;
(4) Intrastate lakes, rivers, and streams which are utilized by interstate travelers for recreational or other purposes;
(5) Intrastate lakes, rivers and streams from which fish or shellfish are taken and sold in interstate commerce; and
(6) Intrastate lakes, rivers, and streams which are utilized for industrial purposes by industries in interstate commerce." 33 C.F.R. §209 (1975)(intro. material at 19766).

112. 19 St. Louis U.L.J. at 211.

113. United States v. GAF Corp., 389 F. Supp. 1379 (S.D. Tex 1972); contra, United States v. Phelps Dodge, 391 F. Supp. 1181 (D.C. Ariz. 1975).

114. See United States v. Gerlach Live Stock Co., 339 U.S. 725 (1950).

115. 42 U.S.C. §4001 et. seq. (1973).

By Jay Fountain
and
Dwight Cochran

FINANCING STORM WATER CONTROL PROJECTS

When Herb Poertner first asked me to speak on the subject of innovative methods of financing storm water control projects, being a person attuned to the systems approach to problems, I of course approached it in a normal, logical manner, trying to ascertain what innovative approaches were being utilized presently by local governments and thinking that throughout the United States certainly a lot of governmental administrators must have approached this problem of an innovative method.

I started by talking to local governments--the City of Atlanta, DeKalb County--and my own unit of government, Fulton County. The consensus reached among those governments was basically that the best way of financing storm water control projects is to ignore them; just don't do them at all if possible. My first response to this was "Hmmm, is that exactly the way to go about something like this?" So, to endeavor to find out more information, we sent out questionnaires to approximately 100 cities and counties throughout the United States. We requested them to feed back information to us concerning what methods they have used and are currently using for financing storm water control projects and what innovative approaches they could think of and would like to see pursued.

We received 21 responses. From the 21 responses, I obtained sufficient information on innovative methods to perhaps compose a speech of one to two minutes. Since I did not feel like this would be satisfactory for a seminar of this nature, I decided to take a different approach. Generally, the approach used in addressing local government financing problems is similar regardless of the type of problem being confronted; and, of course, being a proponent of management by objectives, I believe in first stating and identifying the objectives to be accomplished. So, the objectives of my talk are basically (1) to develop criteria that can be utilized in evaluating various proposals, both current and future, for financing storm water improvements; and (2) following directly from one, to develop some equitable and efficient approaches to financing storm water improvements.

Many people have serious questions about the utilization of the management-by-objectives approach, especially in a speech. I would like to relate back to an illustration given by George Odiorne, one of the founders of the management-by-objectives approach. He was working in the railroad transportation industry--specifically with traffic controllers--and finding the going very difficult. He was meeting with a particularly obstinate and difficult supervisor on the East Coast in an effort to understand some of the problems of the industry and some of the difficulties this person was having. During the course of the conversation, he got around to talking about the various district supervisors--people in various areas who were working for this person. The person related to him that he had one particularly bad individual (for the record, we shall call him Joe) working in his mid-west region. He related that Joe just couldn't do anything right. He spent his time doing things that probably were of no use, and never seemed to get around to doing things the supervisor wished him to concentrate on. It seemed that Joe made the wrong decisions in almost all instances, and the supervisor just couldn't decide what to do with him. Odiorne said, "Sometimes that is a common perception of Management. Let's do a check on it. Write down exactly what you would like for Joe to accomplish within the next six months; and when we get together again, we can determine if what you have been relating to me is true." They proceeded to write the objectives that this supervisor had for Joe over the next six months.

Several weeks later Odiorne was visiting the mid-west office and ran into Joe. In the middle of the conversation Odiorne stated that he had seen Joe's boss in New York; and Joe related to him,"I'm really in trouble. I just can't do anything that pleases my boss. I'm just about to get fired. It's really terrible. I don't know. Maybe we just think on different wave lengths. I just can't get through to him."

Odiorne turned to him and said, "Well, you know, it just happens that this subject came up when I was talking to him, and we wrote down your objectives for the next six months--what your boss expects you to do and to accomplish."

Joe looked at him and his face lit up: "You know, I'd do anything to get my hands on that. It would probably save my job for me." "George," he says, "let me give you $100 for that, please."

Odiorne said, "No, wait a second! Hold it! You can't bribe me. But I'll tell you what: It's on top of the things in my briefcase. You give me a dime and I'll go get a cup of coffee. While I'm gone, you take it out and copy it; and I won't know anything about it."

Six months later Odiorne was back in the East Coast office talking to Joe's boss and relating what had happened in various areas when the subject of Joe came up. Odiorne said, "Let's look at his objectives and see how well he has done against those you said he should be doing and see how bad he really is."

The boss said,"It is just amazing to me. Joe has turned around completely. He is my best controller now. You know, everything I seemed to want him to do, he is doing. He is ignoring those things that I don't think are important. He is really concentrating his efforts in the proper directions and getting a tremendous amount accomplished."

Odiorne cleared his throat and looked at the guy and said, "You know, I hate to tell you this; but, I happened to be out there with Joe a few weeks after you and I met, and I gave him a copy of your set of objectives for him."

The boss sat back with a stern look on his face and really got almost angry about it. He said, "I knew it. That SOB cheated!"

Odiorne told him, "I think people deserve to know where they are expected to go. Of course, it does put us on the spot and makes us toe the line and really strive to accomplish something. I hope today we will be able to do so."

Generally, in an overall approach to the topic, I want to briefly review some of the traditional methods of financing storm water improvements, discuss some of the strengths and weaknesses of these methods, and then work with you, the audience, in developing criteria to measure the equity, efficiency and effectiveness of various financing methods. After that is done, we will apply these criteria to traditional methods, determine how well they rate, and try to derive, from the criteria, some innovative methods that would provide us with sources of revenue to fund these proposals.

In reviewing the traditional methods of financing storm water improvements, there are: the use of current ad valorem taxes and other sources of general revenues; the use of GO bond issues--either small annual issues or large periodic issues; the use of special assessments based on front footage, square footage of property, etc.; the use of private funds, mainly from developers, to fund storm water improvements and new developments; the use of revenue sharing; the use of water and sewer revenue bonds and renewal and extension funds; and the use of community development act funds or other state and federal sources. How effective have these methods been and how equitable are they in their use at the present time?

(1) Current Ad Valorem Property Taxes

This is a good source of revenue; and large amounts of money can be raised from it or, at least, could have been in the past. However, there is presently a lot of pressure because of other increases, especially in educational costs and costs of other services, to hold the line on taxes. Also, I have questions myself with regard to the equity of funding storm water improvements from ad valorem taxes without any other consideration being used.

(2) General Obligation Bond Issues

This, of course, tends to delay the cost of the project and allows you to spend monies today before inflation increases these costs. You must pay it back over a period of years; and the current interest rate on GO bonds is now up over 6% in most municipalities and, in some areas, approaching 8%. This means the interest rate is probably approaching your inflation rate. If so, one of the main purposes of utilizing this source would be defeated in and of itself. Also, it is extremely difficult at the present time to obtain voter approval for GO bonds; and there is much competition for capital improvement money provided by small annual issues that voters may have already approved.

(3) Special Assessments

These are probably more equitable than most other methods because, in this case, you are assigning the cost back to the person owning the property. However, they are basically only suitable for a small portion of the total cost of the storm water improvement system and, in many instances, are only charged back to abutting property owners and not those who may be reaping benefits from the system but are not directly in line with it or on it. Also, the source of revenue is not great enough to fund the massive improvements needed in fully developed areas, especially where old, combined systems are causing problems, such as the overloading of sanitary sewer plants and the bypassing of plants in heavy rainfall times.

(4) Private Funds - Mainly from Developers

Here again, equity is very high. However, they are effective only when you are in the beginning stages of development of an area. It is sometimes impossible, or at least impractical, to go back and see developers after construction has been completed. This also probably results in passing on the cost to the buyer of the property, thereby increasing that property cost and, depending upon how the developer passes this on, could have an effect upon location decisions of businesses and individuals.

(5) Revenue Sharing and Community Development Act Funds

The use of revenue sharing and community development act funds are hard to evaluate from an equity standpoint. Because of the fungibility of these funds, they could be considered almost like any other general fund sources of revenues. Also, the competition for such funds is very high and the priority decisions would have to be reviewed. It is doubtful that funds from these sources are sufficient to make a positive impact upon storm water improvements, even though they could probably help in many areas.

(6) Use of Water and Sewer Revenue Bonds and Renewal and Extension Funds

Here, the cost is being borne by the user of the system. This means that the person would pay for storm water improvements based upon his water usage, which is questionable to me with regard to equity. However, in cases where there are combined water and sewer systems, this can be utilized somewhat more effectively.

Now that we have discussed the traditional methods of financing storm water improvements and briefly critiqued their strengths and weaknesses, let's see in what direction we can look for developing a framework in which you can work in the future to establish an equitable, efficient and effective means of financing these projects.

In this discussion I cannot take credit for all the ideas that have come forth since this part of the speech was done on a feedback basis with complete audience participation in the development of criteria to measure the efficiency, equity, and effectiveness of various funding methods. However, I believe that I can adequately summarize what took place. When looking for criteria, what we are endeavoring to find are quantitative and objective measures that can be applied to past or potential funding methods. The purpose of these criteria would be to give the evaluator some legitimate, logical method of assessing the funding method and its applicability to the given situation. Based on our feedback and brainstorming session, the criteria can be broken down into three basic areas.

(1) First would be the effect of this program's expenditures upon other programs: i.e., what priorities do stormwater management projects have vis-a-vis other programs, and what effect would the individual funding method have upon the ability of the programs?

(2) Second, under the general heading of equity, we had to look at the beneficiaries of the program. This could be further subdivided into two areas--direct and indirect beneficiaries. Direct beneficiaries include abutting property owners, down stream property owners,motorists, construction trades and developers. Indirect beneficiaries are politicians, environmentalists, future generations, property owners throughout the region and down river communities. Also, under the general topic of equity would be those things that are causing the problems. In this area you would have motorists using streets and parking areas; development--especially high density and along flood plains; lack of control upstream; poor planning; rainfall; other natural factors such as type of geography; soil density and ground cover.

(3) The third major area is efficiency. Under efficiency would be the ability to pay, cost of collecting, effect of the financing on other programs, the legality of the method of financing, the political feasibility, deferred versus present cost, and the source of revenue--also, what regulations must be complied with and whether or not the quantity of funds available will satisfy the needs.

In evaluating our traditional methods of financing storm water projects by the criteria we have developed, it appears that each has varying degrees of equity, efficiency and effectiveness; but none has qualities sufficient for us to state that this is the best method for financing all storm water projects.

If traditional methods do not give an absolute answer, should we look to those who contribute to the problem or benefit from its solution to assume a reasonable portion of the cost of storm water projects? In my opinion--yes. What are some options that might be pursued as supplements to traditional methods or wholly on their own merits based on our earlier criteria? Property owners within an affected area, not just the abutting property owners, could be assessed on some land measure (square footage, etc.) times a runoff coefficient. The runoff coefficient is the percentage of the storm water that will need to have drainage provided for it and is influenced by the type of ground cover and the slope of the land. Another way to assess property owners within an area is to use a tax levy based on land value or total property value times the runoff coefficient. Problems or lack of problems with storm water drainage affect land value. Part of the auto license tag fee could be placed in a pool to be used for drainage projects. Federal highway development monies might be tapped for some local projects. Developers could install drainage systems at their own expense or provide these funds through a building permit fee based on the type of development. Combinations of various funding methods will probably be more equitable and efficient and can also be used jointly with traditional methods, when applicable.

In conclusion, we are still unable to say that there is one method that should be used for financing storm water projects. It appears that each proposed project has its own set of causes and beneficiaries, and using the same financing method for all projects would result in gross inequities. Each project has to be examined by itself, and its financing arrangements evaluated in a manner that will provide equity, efficiency, and effectiveness.

FINANCING STORMWATER PROJECTS

by W. Joseph Shoemaker
Shoemaker and Wham, Attorneys
Denver, Colorado

Financing stormwater projects is a part of identifying the problem and knowing, legally, that you or someone else has the authority to do something about it, and determining who is going to benefit. From the knowledge concerning the beneficiaries, you can take a position on who should pay.

I think that the best analogy on drainage is that it is a "utility". It is like having clean water come to your faucet. It is like flushing your toilet and knowing that somebody is going to take care of it. It is like knowing that your trash will be hauled away from your residence. Those services are, traditionally, provided on a fee basis. Airports are provided on a fee basis. Local government history of financing public works has been through special assessment districts. If you build a street or sidewalk, the owner of property that fronts on that street or sidewalk pays his share of the total cost. A sanitary sewer is financed about the same way. However, the frontage assessment method has never worked with drainage improvements.

I believe that we must work on a drainage basin concept. The amount of water that goes downhill, in excess of that which would naturally exist, can be computed. The local taxing authorities have records of each piece of real property, with descriptions of improvements thereon. Therefore, it is possible to determine the amounts of both pervious and impervious areas. This makes it possible to determine who is causing the problem in a specified drainage basin. Also, the amount and rate of stormwater runoff from each piece of property can be computed. This is fairly standard in engineering technology, but translating that technology into "financing" is the problem.

The average citizen doesn't have the slightest conception of what "urban stormwater management" is. But they worry that it may cost them some money. I have found that, from a purely drainage standpoint, if you can incorporate in a planned improvement a park, recreational facilities or health facilities with the drainage improvements, the chances of getting someone to pay are better. First it is necessary to get the legislative body of the local government to pass an ordinance that says "an improvement will be built". Then, it is necessary to determine who is going to pay for the improvement, based upon how much extra runoff or increased flows each property owner is sending downhill.

I claim that a vacant lot should not be specially assessed because it doesn't increase runoff flow rates above historic flow rates. If you determine the flow rates and amount of runoff that went downhill before development, the general property tax fund would pay for handling this historic runoff fraction.

In 1968, I wrote an article titled "An Engineering-Legal Solution To Urban Drainage Problems".(1) In 1974, I wrote an article titled "What Constitutes Benefits for Urban Drainage Projects".(2) The definition of benefits for urban drainage projects is discussed in the latter reference. I searched the Colorado State Statutes and found 32 different places where the statutes refer to "benefits", but I did not find any definitions in the statutes of the meaning of benefits. This is why the courts have always determined what constitutes benefits. I reviewed all the court language I could find from all jurisdictions in the United States, including references to health, public works, street cleaning and others. Using this information, I developed a definition of benefits and amended each of the 32 sections of the statutes where references were made to "benefits".

It is necessary in a given case to prove that a benefit will result. You must do your homework. For example, you must prove: alleged increases in runoff volumes or flow rates; expenditures made by the local public works department over the years in cleaning the streets in the specific location involved; or whether a health problem was, or will be, alievated by the improvement.

The definition of "benefit" that I developed is as follows. The term "benefit", for the purpose of assessing a particular property within a drainage assessment district (or special improvement district), may include any one or more of the following:

a. Any increase in the market value of the property;

b. The provision for accepting the burden from specific property for discharging surface water onto servient property in a manner or quantity greater than would naturally flow because the dominant owner made some of his property impermeable;

c. Any adaptability of property to a superior or more profitable use;

d. Any alleviation of health and sanitation hazards accruing to particular property or of public property in the district if the provision of health and sanitation is paid for wholly or partially out of funds derived from taxation of property owners of the district;

e. Any reduction in the maintenance costs of particular property or of public property in the district if the maintenance of the public property is paid for wholly or partially out of funds derived from taxation of property owners of the district;

f. Any increase in convenience or reduction in inconvenience accruing to particular property owners, including the facilitation of access to and travel over streets, roads and highways;

g. Recreational improvements accruing to particular property owners as a direct result of the drainage improvement;

h. The dollar value or values of any one or more of the above ("a" through "g") accruing to a specific parcel of property or the total property of a taxing entity shall be determined as related to the cost of the specific improvement.

In terms of financing, I believe that it is necessary to be very specific. This belief led me to develop a definition of benefit. Then, there are many ways to finance projects. At the local level, stormwater projects are basically a public works function. But, it is often possible to develop multiple-purpose projects. For example, we hope to clean up the South Platte River and to develop a linear park in conjunction with this. From a recreational standpoint, we have two 1-mile sections completed. Our criteria was that the River must be boatable from beginning to end--for kayaks, canoes, rafts and tubes, but not motorboats. Secondly, we required a hiker-biker trail, full length, along one side of the River. This is being built of concrete, 5 inches thick, 8 feet wide,and is designed to resist destruction from floods, including the 100-year frequency flood event. The criteria also required that the linear park tie in with existing City facilities.

I included discussion of this improvement here for the purpose of illustrating how it is possible to sell a proposed financing arrangement by turning somebody on, either the citizens, the politicians, or both. Although stormwater management appears to be difficult to finance today, I believe that the situation is favorably influenced and supported by recreational, ecologic, environmental and aesthetic goals and programs. These aids were probably never considered in the old days in financing drainage improvements.

At the local level, in Denver, we have several methods available for financing stormwater projects. We can use special assessments. I believe that it will be easier to do this now because we have identified and studied many of our drainage basins, and the definition of benefits has been made clear. We can also use general obligation bond issues.

By planning stormwater management improvements to be aesthetically pleasing and serve multiple-purpose uses, such as we are doing along the South

Platte River in Denver, the local citizens will lend their support, and financing is made easier. My solution to financing stormwater projects, for both pollution control and flood control, is to build a citizens cadre of "identifiers and complainers". This will come about as a result of the hiker-biker trails that we are constructing along the natural waterways within the floodplain. People using these trails will identify the polluters and the obstructors. They will help in identifying the locations of point pollution. I promote the use of the River for recreation such as kayaking, canoeing, tubing and rafting. This helps to create an awareness of River conditions, including cleanliness, on the part of the River users and their families, friends and acquaintances. I often take legislators down to the River for lunch so that they will develop a first-hand awareness of the need to clean up the River. Sooner or later, I will get a State appropriation of funds to help build more trails. I will also get enough people at the State level who will monitor the River, with the most technologically advanced equipment available, to pinpoint the sources and extent of pollution. I do not believe that present river monitoring techniques are good enough. I don't know of any place in the United States where water quality is monitored adequately. If I did, I would try to have the same done in the Denver area.

Another problem is that the floodplains of the waterways in the Denver area are not marked so that the laymen know where the floodplain is. The Drainage District plans to install a system of permanent markers along our major waterways to identify the location of the 100-year floodplain. This may mean painting a line on someone's building. The District is also developing maps to be mailed to each property owner. These will inform each property owner of the drainage basin in which his property lies, the location of his property, and the boundaries of the 100-year floodplain. These will be recorded in the

Recorder's Office in the various counties involved so that this information will be available to prospective purchasers of property when a title search is made. This is a controversial procedure, from a legal standpoint, because such information could queer a sale of real property, or cloud the title. My position is that local public officials have an obligation to do this. Sooner or later, some citizen will sue a public official for not spreading this information on public records.

Most people, including myself, believe in and support the national goals of clean water in our natural navigable waterways and unobstructed flow of these waterways. But, it is necessary to develop workable financing plans as well as engineering plans for achieving these goals. It is necessary to prove that health and safety, as well as quality-of-life, are involved. When you get your homework done properly and fully, there won't be any problem getting money because there is much money available for stormwater management. This applies at the local, state and federal levels.

The Platte River Development Committee, of which I am chairman, is cleaning up the South Platte River in Denver. For financing, we have several sources in addition to the City and County of Denver. These include the Bureau of Outdoor Recreation, HUD's Community Development Program, the State Department of Parks, the State Highway Commission and others. We may also have to charge property owners, but this is the most politically controversial method of financing.

REFERENCES

1. Shoemaker, W. Joseph, "An Engineering-Legal Solution to Urban Drainage Problems", Denver Law Journal, Vol. 45, 1968, pp 381-398
2. Shoemaker, W. Joseph, "What Constitutes Benefits for Urban Drainage Projects", Denver Law Journal, Vol. 51, No. 4, 1974, pp 551-565

QUESTIONS AND ANSWERS

(Following W. J. Shoemaker's talk "Financing Stormwater Projects")

Question: Can you tell us about the water rights issue as it relates to stormwater?

Answer: For Colorado, my position on water rights is that there is no accurate way to "appropriate" surface runoff. In Colorado, you must identify how much water is involved and you must prove that you can put it to some beneficial use. Because stormwater is so erratic, in terms of when it comes, you can't rely on it for a beneficial use. I have never had any problem with giving advice on drainage problems. My position is that you may do with drainage water whatever you wish, so long as you don't damage someone's property, upstream or downstream.

Question: You talked about the multiplicity of federal agencies, involving coordination at the state level in Colorado. Please explain this.

Answer: That is in the statute. The coordinating agency is the Water Conservation Board, with respect to floodplain management. With respect to water quality, the responsibility lies in the State Health Department. The Department of Natural Resources has a big interest in both subject matters. The ultimate answer to your question is tied in with the funds appropriations made by the Legislature. In Colorado, the Legislature has funded the State Department of Health adequately on water quality. We have funded the Water Conservation Board adequately to make funds available to local governments for identifying flood hazards. And, we have funded the Department of Natural Resources adequately, so that its parks unit and fish-and-game unit can get into the act.

Question: (Erik Edeen): Given the Colorado water rights laws, could water quality management practices conflict head-on with good water resource management practices, particularly with regard to irrigation in rural areas? Do you envision a rewriting, or change, in Colorado water rights laws?

Answer: Yes. This is very controversial when you put it in that context. I wouldn't put it in terms of the Legislature changing water law. I would put it in the context of the State Department of Health and Water Quality requiring something, or the Department of Natural Resources, from a recreational standpoint, requiring something. We succeeded in passing a statute that said something like--"our navigable streams must have a certain average annual flow for recreational purposes". This is a very controversial subject, because of water appropriators downstream. When they make a demand on the river for water, they are entitled, under Colorado water law, to get it in accordance with their water rights. I am working this out on the Platte River in connection with Chatfield Dam and Mt. Carbon Dam so that the State Engineer will send the water down the River to the irrigators on Fridays, Saturdays and Sundays--instead of Mondays, Tuesdays and Wednesdays. This will give our kayakers and canoers 100 cfs in the River on days when they most want to use the River. I think, administratively, there is a solution to that problem.

Question: In Colorado, does a city that generates additional runoff, due to land development, have any rights to that water?

Answer: I do not think so, for the same reason that I don't believe that anyone who wants to appropriate runoff waters has been very successful. I have discussed this subject with the Denver Water Board and, at one time, they thought that they would try to file on Harvard Gulch which has 4 to 5 cfs coming from the shopping center upstream and irrigation of lawns. But, the Board decided that they could not appropriate that water because that surface water has historically been in the stream and the Board had no more right to it than did someone else. I think it would be difficult to have such a claim stand.

Question: (Michael Seaman, Snomish County, Washington): You said that the courts recognized natural flow. There are very few pristine streams. What is the definition of natural flow?

Answer: I think that depends on historical records. Natural flow depends on rainfall in some locations along a stream. In other places, it depends on snowmelt and rainfall. It may also depend upon what man-made things may have been constructed, such as a dam or a detention reservoir. These must all be taken into consideration in determining what the natural flow of a stream is.

Question: (Roland Gow): The State of Colorado has the ultimate authority for monitoring the quality of waters in the state. That authority could possibly be delegated to local health departments. Would you be willing to support increased State funding for delegation of that authority, with pass-through funds to the local governments for monitoring purposes?

Answer: Probably. The City and County of Denver thinks it has the ultimate authority because it is a home rule city. But, in either unincorporated areas or statutory cities, I think that the State has ultimate control. Because it should be the goal of the State and Congress to have clean water, the State should fund monitoring. The State has funded monitoring of seven personnel positions so as to organize a system for the very thing you are talking about. The State funds local health departments, but does not specify how the funds will be expended. The amount of State funds allocated to local health agencies is $ 1.10/year/capita. The local governments determine how they will use the money. But, I think we could write into the statute that a certain amount of this has to be used for monitoring.

Question (Robert Braun, Idaho Dep't. of Health & Welfare): Please cite the reference on your article "What Constitutes Benefits for Urban Drainage Projects"?

Answer: Denver Law Journal, Vol. 51, No. 4, 1974, pp 551-565. Incidentally, the State of Colorado, in the last session of the Legislature, passed a statute which reads exactly as the conclusion of that article--minus the words "aesthetic" and "ecological", in paragraph g.

PLANNING TO NARROW THE IMPLEMENTATION GAP

Presented by Penelope Wilson
Special Assistant to the Executive Director
for Richard Page
Executive Director*

EPA URBAN STORMWATER MANAGEMENT SEMINAR
Denver, Colorado
December 4, 1975

Dick Page asked me to express his regrets. However, he had made several commitments that made his schedule this week somewhat inflexible and simply could not manage to accommodate a morning session rather than an afternoon session.

Mr. Waldo and Senator Shoemaker did an excellent job establishing the premise for my comments. Any discussion of intergovernmental relationships and the legal and financial aspects of developing management schemes for urban stormwater is usually most discouraging. The complicated relationships involved and--in many instances--the lack of specific financial or institutional tools make the gap between planning and implementation seem unbridgeable at first glance. Senator Shoemaker gave us some good advice for bridging that gap. Perhaps you will find a discussion of the techniques we are using in Seattle helpful as well.

In Seattle we are relying heavily on our 208 planning process to develop the institutional and financial mechanisms we need to deal with urban stormwater problems which--not surprisingly--constitute the Puget Sound area's most serious water quality problem. My boss, Dick Page, often remarks that whenever he comes away from an intergovernmental discussion of these issues, he finds himself feeling very grateful for his graduate training in foreign affairs. When he was in graduate school, he thought he would be applying the principles involved in case studies of the international diplomatic triangle to the foreign service. The diplomatic triangle is simply a conceptual label for the practice we are familiar with among Russia, China, and the United States. Two of the three parties are forever joining forces to undermine the third. Alliances shift from issue to issue and from day to day, however, so no one is ever quite certain who is odd-man out. We have experienced--and still are experiencing--a good deal of that in Seattle as the regional planning agency, the counties, the cities, and Metro maneuver for position and a slice of the 208 planning pie.

While no one wants to actually operate the stormwater utility, everyone seems to see 208 planning for non-point source pollution control as a convenient vehicle for exercising some real political leverage. 208 has come to represent the planner's "last best hope" for controlling land use and, as such, it could be the most powerful planning tool still remaining to local officials. That means it is a highly sensitive issue--presenting lots of opportunities for forging good inter-agency working relationships and, more importantly, for producing results--and, on the other hand, laden with the potential for some very damaging confrontations which could polarize relationships and delay projects for several years. That is why it is essential that a lot of thorough analysis about existing and potential institutional and financial arrangements accompany the groundwork for developing stormwater management strategies. In other words, it takes political savvy as well as engineering and technical expertise to put together a management plan that can be implemented.

---

* Municipality of Metropolitan Seattle; Seattle, Washington

In Seattle I think we got a big jump on narrowing that implementation gap by winning 208 designation for Metro which is the area-wide water pollution control agency--rather than have it assigned to the regional planning council. Our local officials took the position that water quality planning should be done as close to implementation as they dared and, therefore, they petitioned the Governor to have the 208 assignment go to Metro rather than the Council of Governments. Speaking as I do from a vested perspective, I feel compelled to point out that Metro had some impressive credentials to back up its petition for 208 designation. Metro was management agency in a basin planning effort for water and waste management which included an urban stormwater plan funded by the Corps of Engineers. The water quality management plan of that basin planning effort--which was just completed last summer--involved an extensive and very sophisticated data gathering program which included developing computer models of the two river basins. So, we had already completed substantial portions of the data gathering and problem identification efforts that other areas are now undertaking as part of their 208 planning programs. The technical information and experience gave us a head start in undertaking 208 planning.

We also had learned a great deal about intergovernmental planning efforts during our river basin planning experience. That involved an inter-agency advisory committee made up of about 15 bureaucrats who met twice a month for four hours at a time--over a three-year period--to guide the work of the consulting teams doing the river basin plans. In addition, our Metro Council is a federation of local governments with 36 officials--about 30 of them locally elected--sitting on it. They formed a committee to provide policy guidance during the river basin planning effort and that committee met monthly during the three years. So, the river basin planning effort had given us some political experience as well as some technical information and expertise.

It was in that experience that we developed the conviction that planning should be done as close to implementation as we dared. This does not mean ignoring the comprehensive planning considerations that are fundamental to the Council of Government approach to planning. It does mean working out an understanding with the COG as to what those considerations are--and how they can best be addressed.

IMPLEMENTATION GAP

We did this in preparation for our 208 designation through a memorandum of understanding with the COG. In that memorandum we identified comprehensive planning as the development of generalized goals, objectives, and policies to guide the orderly growth of the region. Functional planning was defined to mean all planning related to the development of facilities, systems, and programs. Functional plans had to be consistent with comprehensive plans and, furthermore, functional plans had to rest on the same body of demographic data and projections developed in the comprehensive planning process. With those assurances, the COG could be certain that plans contravening regional policy would not be developed in the 208 process...that it would remain sensitive to regional policies regarding growth, allocation of development for housing and industry, transportation services, etc.

Since these are the issues that are normally the source of friction between facility planners and comprehensive planners, we believed we had made a significant step toward reducing implementation barriers by developing that agreement before we even began the planning effort.

Perhaps the greatest barrier to implementation of any plan--particularly one done in the consensus atmosphere of the regional planning council--is the fact that no one with the power to implement it will claim it as its own. It is like an illegitimate offspring in that the potential parentage is impressive--but when it gets right down to it no one will really admit to being the father. We experienced problems like this in the development of our river basin plans for waste management--and we are doing everything we can to avoid a repeat of that this time. We have called the technique we are using collaborative planning, and the purpose is to develop ownership of the plans with the local general purpose governments who will be implementing them.

So far as anyone can predict right now, Metro will have a limited role in implementing an urban stormwater management plan for the area because the taxing, zoning, permitting, and other legislative capabilities required to enact such a plan rest with general purpose governments. We must have a partnership role with them, however, for two reasons: First, because the design of strictly storm drainage systems must consider the water quality impacts on the receiving waters, a responsibility of Metro in King County; second, because of the nature of the combined sewer systems which were built in Seattle and a couple of the other large suburban communities. Metro's computer controlled sewerage system can store large quantities of stormwater to mitigate or prevent overflows in the area's waterways--thus, any management plan must rely to some degree on this very important tool.

However, most of the innovative techniques required to solve the urban stormwater problem are of a financial or institutional character and will require actions by local general purpose governments.

Recognizing this we have developed a program which will permit the City of Seattle to do a pilot management plan for the very critical Lake Union basin and a creek that runs through the densely populated north end. King County will do a pilot management plan for one of its critical creeks. In each case, the plans will be done by local staff under Metro's management with Metro's 208 planning funds. Metro will develop area-wide strategies relying on the specifics of these local basin plans to provide policy guidance to the overall strategy development. In this way, the basin-specific implementation plan will be the product of the implementing agencies. The inputs from these plans to the area-wide strategies should assure ownership of the master 208 plan on the part of the local planning bureaucracies.

Lake Union is an urban lake characterized by extensive commercial and residential development on its perimeter and polluted from stormwater runoff which is made more serious because of the city's old combined sewer system. We have been telling EPA for some years now that combined sewer separation will do a great deal more to improve the quality of water in the Seattle metropolitan area than will imposition of a secondary treatment requirement on Metro's large West Point plant which discharges into Puget Sound. We believe the 208 planning process will permit us to demonstrate that pretty effectively--but the timetable is such that we will be completing the 208 plan in 1977--about the same time that the secondary treatment requirement goes into effect. Metro's NPDES permit now gives a waiver from that time requirement while efforts continue on planning to meet the 1983 Best Practicable Treatment requirement. That BPT planning effort under a 201 facilities planning grant is continuing in parallel with our 208 planning program.

I am telling you all this only to point out that one of the barriers for implementation of an urban stormwater management plan--in Seattle at least--could well be other provisions of Public Law 92-500 which require the assignment of high priorities to compliance with treatment requirements--requirements which in our case, at least, we believe to be unnecessary. If the regulatory mandate regarding secondary treatment remains in effect, sewer separation would move so far down the priority scale that it is unlikely it would ever be funded.

The fourth method I would like to suggest for narrowing the implementation gap is opening up the planning process. This is accomplished to some degree in the collaborative planning process that I suggested earlier. But the method I am thinking of especially in this fourth step is using the environmental impact assessment process to really open up your planning efforts to a thorough and critical analysis which would be both objective and subjective in nature. We believe this is a very useful way of preventing the myopia that can occur when operating agencies do their own facility planning. We have structured our organization in such a way that the planning and environmental impact assessment process occur in different divisions, but report to the same department director. This is important because it means that both are on the same critical path in terms of goals and objectives--yet they have their own staff resources to allow independent analysis and the kind of critical, searching examination that all planning alternatives should receive. If the environmental assessment process were outside of the same decision-making system as the ongoing planning effort, delay or postponement of the project might appear to be a viable option to those engaged in preparing the assessment. This could lead to inter-agency bickering which is costly to the public and which merely serves to increase mistrust of public institutions. But when the impact assessment process is kept within the same decision-making system, the incorporation of other alternatives or viewpoints in the planning effort is encouraged. And the critical path--which is so essential if plans are to be implemented--is maintained. We believe that this will assure the production of implementable plans rather than wish books--and we think this is the kind of mandate that we have from the public which has expressed growing dissatisfaction and frustration with plans that are never implemented.

The fifth strategy for narrowing the gap also involves opening up the planning process--by designing into it the means by which citizens can effectively participate in planning. That is a pretty tall order--effective citizen participation--but it is one we are committed to simply because we believe that it does assure an implementable plan. We are designing our participating effort for the 208 planning program to develop a citizen constituency for the plans. And, in order to do that, we know we have to listen and respond to what the people in the community want to do about stormwater management.

We gained a healthy respect for the complexity of designing implementable stormwater management plans during our river basin planning effort because the stormwater management study attracted more public participating than did any of the other water and waste management studies. We found that stormwater problems are the source of considerable public frustration and cynicism. And we developed a real empathy for the general purpose government people who must attempt to implement management programs. It became obvious that people in different areas of the community disagree completely about the appropriateness of various management solutions. One entire residential area of the county was more than content to put all the runoff in a culvert and viewed the wetlands and streams other areas are so anxious to preserve as nothing more than an expensive nuisance. Yet, another area considers any impact on natural streams as the grossest kind of violation.

It became obvious that neighborhood solutions were expected by the community--and that those solutions had to be based upon equitable financial plans. The concept of equity was hotly debated, and we still are not sure quite what we heard because the people who attended the meetings on stormwater runoff were usually those living at the bottom of the hill where the most severe problems occurred. They wanted to assess those who "caused" the problems the most with the rate structure to be based on the amount of impervious surface, etc.

One of the suburban communities, Bellevue, was way ahead of the rest of the county in trying to deal with the stormwater problem. It had a very influential citizens committee which worked hard to develop a utility approach to the drainage question. Community meetings on the utility proposal were well attended, and there appeared to be a concensus for the plan. After several public hearings, the City Council approved the plan and--four months later--hastened to abolish it after the first billing of the utility provoked the circulation of recall petitions. Most observers believe that Bellevue's case was not a fair test since there was a snafu in the billing procedure and the first utility bill was for four months rather than two months. Furthermore, Bellevue made a mistake in billing customers long before there was any evidence of stormwater improvements. But the lesson did point out some valuable things to remember about narrowing that implementation gap. The most obvious two are--don't rely completely on the citizens who attend meetings to give you a reading of community sentiment. They are usually atypical--particularly in their attitudes towards improvement projects. The second is that in implementing new service--always be sure that the service precedes the bill and don't allow your collection department to make a unilateral decision about billing procedures.

To avoid total reliance on the elitist and participating citizen, we have developed a mix of citizen participation techniques for our 208 process which include random sample telephone and mail surveys, attending meetings of existing organizations to take a reading on their attitudes and desires, focus interviews of representative groups, and the use of direct mail to encourage neighborhood residents who may not be affiliated with an existing organization to learn about the planning effort.

In addition, Metro has a water quality citizens advisory committee which we staff and which will provide advice and counsel on the policy issues in the planning effort. The committee is comprised of a variety of age and income groups and represents a geographical balance. It was appointed from lists of nominees submitted by environmental and sportmen's organizations and from elected officials on the Metro Council. Council members and citizens selected the committee members, and it was one of the most hotly debated issues before the Council--which indicates, I think, a growing recognition on the part of elected officials that citizen participation is important.

In addition to that committee, we will work with what we call "constituent" citizen committees interested in one particular water body. This is the ideal way to assure plan ownership. It simply means devising techniques to do what Senator Shoemaker described--ways to survey the way citizens look at and take pride in those streams, rivers, and lakes. It is very risky because these constituent groups often have very definite ideas about what they want to accomplish, and there is a likelihood of producing plans that don't live up to their expectations. But we have found that in some cases these groups of people already have organized. It would be sheer folly to think that we could develop and implement a plan that has not won their endorsement.

In some cases we hope to develop constituent groups of citizens by encouraging them to participate in the planning effort with data-gathering activities like "stream watching". That may sound a little esoteric--but the people in our planning effort think it has real possibilities. We would provide interested citizens with a basic data summary on their stream or small lake and ask them to help us in our data collection by recording day-to-day changes in volume, turbidity, color, temperature, wild-life habitat, and the like. This may seem a little too fundamental to be of much help, but our scientists tell us that the sampling methods we now use to determine water quality are pretty crude and unsophisticated anyway. And, if fishable and swimmable is to be the 1983 goal for water quality, perhaps we need to think now about defining water quality in terms that people can better understand.

At any rate, these stream watchers would begin to take the same pride in observing differences in their neighborhood stream or lake that bird watchers do in seeing a rare bird or discovering a peculiar habit in their favorite old bird. This kind of activity is expected to engender a kind of constituency for the well-being of that water body and an interest in implementing plans for its protection.

The real test of public participation is whether the plans so developed are indeed implemented and that will largely depend on the degree of commitment the public feels and transmits to its elected representatives.

If the public finds the planning effort relevant and compelling, you can bet the elected official will also. And the gap between planning and implementation narrows considerably when that happens.

Now, let me quickly summarize my five general recommendations for narrowing the implementation gap:

1. Do your planning as close to implementation as you dare because this will assure consideration of the realities of implementation which include cost-effectiveness, institutional arrangements, and financial alternatives.

2. If you are an operating agency, be sure that you have worked out a framework for planning with your regional planning agency or

Council of Governments. If you are a COG, I suggest that you work out such an arrangement with the implementing agency. This should address subjects like development of goals, objectives, policies, use of demographic data and projections regarding the timing and location of growth and development.

3. Try using a collaborative approach to developing your plans so that all those who will have a piece of the implementing action also have a role in the planning action. This assures ownership of the plan on the part of the bureaucrats who must implement it.

4. Keep the planning process open to critical analysis and evaluation by thoroughly and religiously utilizing the environmental impact assessment process set forth in NEPA. But try to keep that evaluation process on the same timetable as the rest of your planning effort. This will assure examination of alternatives and should make the adoption of implementable plans more likely.

5. Design opportunities for the public to participate in the planning effort. Be sure you use a mix of techniques so that you get a reading on the sentiment of a variety of publics. Remember that this takes staff time and money to do properly. Do not hesitate to build a constituency for the plan in your community and among your elected officials or it will likely end up in that great never-never land of plans that will never be implemented.

QUESTIONS AND ANSWERS

(Following Penelope Wilson's paper "Planning to Narrow the Implementation Gap")

Question: How big is Seattle Metro's 208 Planning Staff?

Wilson: Our 208 staff is separate from our Community Involvement Staff, and from the Environmental Assessment Staff. Our 208 staff now numbers about five persons. The Community Involvement Staff has an additional four persons working on the 208 planning. Metro has a community involvement staff for transportation and for water quality. It works in the day-to-day operations as well as in planning. The Environmental Assessment Staff numbers about six persons working on 208 planning.

Comment: It sounds to me like you have about 20 persons to draw on, but not necessarily 100 percent of the time.

Wilson: Yes. We can rely on them for various aspects.

Question (Herbert G. Poertner, Engr. & Research Consultant, Bolingbrook, Illinois): I would like to know whether you, and also the representatives of 208 agencies who are here, feel that there are enough talented persons available to employ on present 208 agency staffs. Someone asked--"how big is the staff"? The next question is--do you need more? And other questions that follow are: Can you get qualified people? Are they available? Can you afford to pay them what they demand? Have the country's educational institutions developed qualified persons in past years? Is the staffing problem an impediment to progress in closing, or narrowing, the implementation gap? Perhaps you or others in present here may wish to respond to my questions.

Wilson: I believe that Seattle Metro has a unique situation in that the Seattle area is a very desirable place to live. We do not have as much trouble attracting talent as may possibly be experienced in other parts of the country. However, we don't find the kind of experienced people we want and need for community development. That is something that we have all been learning in the last six years. Much of the federal legislation has mandated it. It is an art that has been developing in the last five or six years. However, in most fields, we don't have much trouble in attracting people. Do you agree with that Rod?

Comment (Rod Stroppe, Seattle Metro): Yes, I think that the question is a very valid one. Because of Seattle Metro's local climate, implementation is a very sensitive issue. The important consideration is not the quantity of the 208 staff; it is the quality. I feel that every agency would like to have someone like Senator Shoemaker, who spoke this morning, to build a constituency and talk to people. In implementation, I think that the most important thing is to use whatever resources are available to put-across the message to the constituency and the bureaucrats so that the plans do not lay on the shelf.

Question: Is your question directed toward the implementation aspect or the planning process?

Poertner: Both. This means that it is desirable to have staff people with technical know-how and backgrounds in engineering and science. This would help expedite completion of the plan so that it can be moved toward implementation simultaneously. I wonder if there are enough people available that have scientific backgrounds, such as water scientists. And, are there enough people available who can interpret the master plans being developed by 208 agencies so that the planning can be moved, concurrent with plan development, toward implementation?

Comment (Rod Stroope): I think that there is enough technical talent available in local areas, or the services can be obtained from consulting firms. But, it is critical, in preparing a plan and implementing it, to develop communications to bridge the implementation gap.

IMPLEMENTATION OF URBAN STORMWATER RUNOFF PLANS

by George C. Berteau
Chairman, Southeastern Wisconsin Regional Planning Commission
Waukesha, Wisconsin

It is as fundamentally unsound to extend the tenets of egalitarianism to all problems occasioned by stormwater runoff, rural or urban, as it is to extend them to personal capacities, and behavioral characteristics. Accordingly, it is necessary here at the outset to make totally clear that these remarks are addressed solely to the water quality problems created by urban storm water runoff, the systems employed or conceived in alleviation of such problems and the factors common to implementation of an adopted plan or system designed to deal with such problem or problems.

It is recognized that previous speakers at this conference no doubt have well defined certain terms and definitions that any areawide water quality planning and management program mounted within or independent of P.L. 92-500, The Federal Water Pollution Control Act, nonetheless, these few basic definitions seem to be in order. Parenthetically, Section 101 (1) (f) of that act provides:

> "It is the national policy that to the maximum extent possible procedures utilized for implementing this act shall encourage the drastic minimization of paperwork and interagency decision procedures and the best use of available manpower and funds so as to prevent needless duplication and unnecessary delays at all levels of government."

Thereafter follows more than 86 pages, printed in small type, ranging all the way from Citizens Suits to the Adminstrators Authority to Award Scholarships.

Now, as to the terms or definitions------

CONVEYANCE FACILITIES - With respect to sanitary wastes, conveyance facilities consist of gravity flow sewers, force mains, sewage pumping and lift stations, and related appurtenances used to collect and convey sewage to sewage treatment facilities. With respect to storm water, conveyance facilities consist of gravity flow sewers, pumping stations and defined drainage channels and related appurtenances used to collect storm water runoff and convey it to a point of discharge to a surface water body.

EFFLUENT LIMITATIONS - Any restriction established by any state or the U.S. Environmental Protection Agency on the quantity, rates, and/or concentrations of chemical, physical, biological, and other constituents which are or are proposed to be discharged from point sources of pollution directly or indirectly into any surface and ground waters, including schedules of compliance with discharge abatement orders. There are two general categories of effluent limitations.

The first category consists of standard effluent limitations for industries and publicly owned and operated waste treatment facilities which are intended to be applied uniformly on a nationwide basis. These uniform or national effluent limitations are not related specifically to the waste assimulative capacity of the receiving body of water. The second category of effluent limitations are those additional restrictions set forth for a given waste discharge when it is found after careful study that the body of water to which the waste is to be discharged will not meet the applicable water quality standards for that body of water if only uniform state or national effluent limitations are applied. Thus, the second category of effluent limitations represents additional restrictions applied where necessary to waste discharges on a case-by-case basis following waste water quality management planning efforts.

NONPOINT SOURCES - The generalized or areawide discharge of waste water into a body of water which cannot be ascribed to a discrete, specific source location. Thus, the term "nonpoint source" refers to the origin of any pollutant not identifiable as a point source. Nonpoint sources most commonly consist of urban and agricultural runoff which carry sediment and certain chemicals which act as water pollutants. It is important to recognize in this respect, that the distinction between point and nonpoint sources of pollution cannot always be sharply defined. For example, urban runoff while in concept a nonpoint source of pollution, when collected in piped storm sewerage systems may be discharged to bodies of water at discrete sites, and thereby can be regarded as a point source of pollution, as can separate and separate and combined sewer overflow outfalls. Such urban runoff, however, when carried in roadside ditches and numerous interrelated swales and water courses, may have to be regarded as nonpoint source.

WATER POLLUTION - A condition in which the quality of water in a lake or stream is adversely affected by waste discharges from human activities or sources so that one or more beneficial uses of the lake or stream is impaired or eliminated. It is recognized that water quality may, as a result of natural causes, not meet the quality standards attendant to specified water use objectives.

WATER QUALITY - The physical, chemical, radiological, and biological conditions of the water determined through the analysis of data and the assessment of the quality and diversity of existing aquatic life. To a large extent the quality of water determines its potential use for propagation of fish and other wildlife, recreation, navigation, and as a source of industrial and domestic water supply.

URBAN AREA - Lands used for residential and industrial purposes, thus, we do not address the matters of herbicides, insecticides and plant nutrients in runoff and eroded soil materials from agricultural and silvicultural lands or biochemical oxygen demand, nutrients and pathogenic organisms from intensive animal feed lots and manure storage areas.

WASTE TREATMENT PLANNING AGENCY - An organization designated by the Governor and approved by the U.S. Environmental Protection Agency to conduct a section 208 Water Quality Planning and Management Program. With respect to our region--the 2686 square miles of seven southeastern Wisconsin counties--the Governor has designated The Southeastern Wisconsin Regional Planning Commission.

Within the framework of the characteristics of the urban storm water problem, you have heard addressed:

1. Urban development and land use as affecting water quality;
2. The impact of combined sewer overflows and storm sewer discharges on water quality;
3. Collector system control;
4. The combined sewer approach;
5. Land use, management controls and practices;
6. Swirl concentrators;
7. Detention flow attenuation as methods, techniques or systems designed to alleviate the water quality problem occasioned by urban storm water.

We could only observe here without going into detail--as that is aside from the basic purpose of this paper--that the problem as defined has been, and is now being, intensified by the ongoing decentralization--the flight from the central city, urban sprawl contained or unrestrained. The old and ongoing method of "improved" channelization of streams to accommodate the larger and faster runoffs--the Underwood Creek in Metropolitan Milwaukee area (Brookfield Suburb) has been widened and deepened four times the normal channel size--due entirely to "urban type" development and concomitant increased runoff. This technique only more quickly passes the contaminants--oil, gas, rubber, asbestos, metal particles, sands and de-icing salts into the recéiving stream and/or larger body of water, wholly untreated, and while producing results satisfactory to developments and the pocketbook of the developer, it totally ignores the adverse effect upon water quality. It is submitted that we now need a shift in emphasis from "discharge" to "absorption" through the infiltration process with such accompanying building codes or zoning changes as are necessary to give meaning to such shift in emphasis--building design, roof storage and contouring must be addressed as well as sediment control for construction sites.

If there is to be effective planning to narrow the implementation gap --that is the span of time between completed plans and partial or total plan implementation, there must be total recognition of the fact that plan implementation measures must not only grow out of formally adopted plans, but must also be based upon a full understanding of the findings and recommendations contained in those plans. Thus, action policies and programs must not only be preceded by formal plan adoption, and following such adoption, must not only be consistent with other adopted plan elements, but should also emphasize implementation of the most important and essential elements of both land use and watershed or basin plans as well as those areas of action which will have the greatest impact on guiding and shaping development in accordance with those plan elements. A single water quality approach--such as usually is pursued by the U.S. Corps of Engineers--"flood control and flood damage abatement", is not recommended in planning to narrow the implementation gap. The water quality problem occasioned by urban storm water runoff is but a single part of achieving basic watershed development objectives and can only be effectively dealt with within the concept of a total watershed or basin plan that addresses at least:

NATURAL RESOURCE PROTECTION - Concern for future residential and urban development so that such development approximates the density and spatial distribution patterns recommended in the land use element, including our consideration of the assimulative capacity as well as load-bearing characteristics of the soil; retention of undeveloped primary environmental corridor lands--probably to be publicly acquired for conservancy, outdoor recreation and related open space purposes;

FLOOD CONTROL - Retention of undeveloped floodways and flood plains in substantially open use--using either floodland zoning, or better, if you can achieve it--public acquisition of these floodlands. Elimination of those areas as existing natural valley storage through encroachment, dumping, filling and structure placement--subservient to the cliche "We need the tax base" in the floodways and flood plains will inevitably destroy the naturally regulated flood-flow characteristics of the stream system, and will result in increased flooding, flood damage and the further impairment of water quality occasioned by increased runoff accompanied by a simultaneous reduction in the natural storage area;

WATER POLLUTION ABATEMENT - With respect to stream water pollution abatement and water quality control:

Overflows from both combined sewers and separate sanitary and storm sewers must be controlled;

specified levels of secondary, tertiary and advanced waste treatment should be provided and obtained in the municipal sewage treatment plants servicing the watershed;

agricultural runoff should be reduced through the institution of good soil and water conservation measures; and

Urban storm water runoff handled in any one or a combination of one or more of the techniques herein before referenced.

The aforementioned precepts that must be observed if the implementation gap is to be narrowed were hammered out on our anvil of experience that includes:

The preparation and adoption of a comprehensive plan for the Root River (Suburban Milwaukee, Racine County and Racine City) watershed--the first major comprehensive watershed plan in our state that recognized that drainage, water quality, and flood control was an areawide problem, intensified by ongoing urbanization, which required recognition of the fact that watersheds be recognized and considered as a planning unit;

The.preparation and adoption of a comprehensive plan for the Fox (Waukesha, Burlington Urban Areas, 946 square miles) River watershed;

The preparation and adoption of a comprehensive plan for the Milwaukee River-a surface water drainage unit, 693.8 square miles in areal extent, discharging to Lake Michigan, with the City of Milwaukee, lying in 9 Wisconsin counties--two of such counties being outside the seven Southeastern Wisconsin County Planning Region;

A comprehensive plan for the Menomonee River Watershed-nearing completion;

A regional sanitary sewer system plan; and

A preliminary engineering study for the abatement of pollution from combined sewer overflow in the Milwaukee metropolitan area.

Active participation in the development of the Kenosha, Wisconsin biological adsorption system for the treatment of combined storm water and sanitary sewage-initiated to determine the engineering feasibility of integrating a high rate biological adsorption process with a conventional secondary activated sludge process to treat combined storm water and sanitary sewage during heavy rainfall periods. These rainfall periods would cause overflows of combined sewers and result in the pollution of the beaches and degradation of Lake Michigan. This project consisted of the idea development, design, construction, operation and evaluation of a 20 million gallon per day treatment facilities at the site of the Kenosha Water Pollution Control Plant.

Active participation in the concept, design and development of "screening/dissolved air flotation treatment" as an alternative to the separation of combined sewers in Racine, Wisconsin-this as a direct result of the Commission's technical work in connection with its comprehensive plan for the Root River-which from its confluence with Lake Michigan in the City of Racine Harbor covers 3.7 miles upstream through an area which includes industrial, commercial, residential and park land usage-some 900 acres containing a network of both separate and combined sewers which have discharge and/or overflow outfalls to the river; there being 53 outfalls-17 of which are separate storm sewer and 36 are combined sewer overflow points.

A study design for the areawide water quality planning and management program for Southeastern Wisconsin-a region which contains 154 local units of government, and encompasses all or parts of 12 major natural watersheds. One of the major elements which that areawide study will address is the preparation of an areawide nonpoint source pollution plan and recommendations for the implementation of that plan. It will focus its attention on pollution attributable to storm water drainage and will develop and publish an urban storm water management guide. This guide will address all facets of the urban storm water drainage problem in the region and will constitute a manual of engineering practice for the abatement of both water quality as well as water quantity problems associated with such drainage. The guide will identify the legal, fiscal, as well as physical, problems involved in urban storm water management: it will review-as you have done these past two days-the state of the art of storm water management; it will inventory regional storm water management problems; propose storm water management objectives, principles and standards; select engineering design criteria and analytical procedures and illustrate their application in one or more sub-areas of the region.

And now, in conclusion, to close the implementation gap-----

At the outset--there should be an agreed upon plan or system--an accompanying schedule of implementing required capital improvements--the plan should be prepared by an agency having technical competence and areawide jurisdiction as a part of an overall comprehensive watershed plan that addresses storm water runoff as one facet of the comprehensive study, and such plan should have evolved by and with the understanding, acceptance and endorsement of the political, environmental and economic leaders and decision makers in the political jurisdictions and area to be serviced; should be supported by citizen input and understanding and hopefully within the constraints of existing institutional structures and legal constraints, for while progress is difficult, change is both suspect and time consuming.

URBAN STORMWATER MANAGEMENT INFORMATION FORM

SUMMARY OF RESPONSES

by Warren W. Gast
Research Consultant
St. Louis, Missouri

EDITOR'S NOTE: An information form was prepared by Herbert G. Poertner and distributed by the EPA to each registrant at the seminars in Atlanta and Denver. A summary was made of the responses submitted by 34 persons at the seminar in Atlanta. A Copy of the information form is included following the highlights of the survey, as presented by Mr. Gast in Atlanta.

OBJECTIVE

The objective of the survey was to ellicit from each seminar participant information concerning the priority needs for stormwater management within the jurisdiction of his agency. Information was also requested concerning the priority reasons for providing solutions and the institutional problems delaying progress.

RESPONSES

The number of responses submitted was far short of our expectations. We had hoped to receive completed forms from 100 to 150 individuals; however, only 34 were returned. Of these, 22 were from representatives of regional planning agencies, 10 were from representatives of state or local government, and 2 were from representatives of private engineering firms.

RESULTS

The questions and results, considering only the top priorities for each question, were as follows:

Question 1. "The Priority Needs for Stormwater Management In Our Metropolitan Planning Area Are:"

1st Priority: Thirty (30) percent of the respondents listed "control stormwater pollution from sources other than erosion to make significant improvements in existing wet-weather quality of streams, lakes, bays, etc."

2nd Priority: Twenty-four (24) percent listed "control stormwater pollution from sources other than erosion to prevent deterioration of wet-weather quality of streams, lakes, bays, etc."

3rd Priority: Eighteen (18) percent listed "control soil erosion to reduce the suspended solids loading in streams, lakes, bays, etc."

Question 2. "The Priority Reasons For Providing Solutions For The Above Needs Are":

1st Priority: Fifty-six (56) percent listed "to safeguard human health and life."

2nd Priority: Twenty-one (21) percent listed "to maintain and improve aesthetics of water bodies and land areas."

Question 3. "The Principal Institutional Problems Delaying Progress In Stormwater Management Within Our Metropolitan Planning Area Are:"

1st Priority: Forty-one (41) percent answered "lack of area-wide policy, criteria, laws and guidelines for development of private and public stormwater management programs and facilities."

2nd Priority: Twenty-four (24) percent answered "lack of needed information and data base in our planning area (e.g. hydrology, native biota, ecology, present wet-weather water quality, etc.)"

3rd Priority: Eighteen (18) percent listed "unmet financial needs."

COMMENTS

An interesting analysis of the responses showed that the priority needs, etc., to each question were very similar for both the Regional Planning Agency representatives and the representatives of State and Local Agencies. The questionnaire's indicated that the top two priorities in each of the three questions were the same for the Regional Planners and State and Local Planners as to the needs for stormwater management, the reasons for providing solutions and the problems delaying progress in stormwater management.

We appreciate the effort by those who completed the questionnaires, and we hope this information is of interest to all 208 agencies.

URBAN STORMWATER MANAGEMENT INFORMATION FORM

1. THE PRIORITY NEEDS FOR STORMWATER MANAGEMENT IN OUR METROPOLITAN PLANNING AREA ARE: (rate by inserting numerals--"1" for highest priority, etc.)

____control "flooding" to reduce depth and areal extent of innundation in developed areas and/or land areas otherwise suitable for development

____control "soil erosion" to reduce silt accumulation in downstream drainage systems or siltation of downstream land areas

____control "soil erosion" to reduce the suspended solids loading in streams, lakes, bays, etc.

____control "stormwater pollution" from sources other than erosion to prevent deterioration of wet-weather quality of streams, lakes, bays, etc. below existing satisfactory conditions

____control "stormwater pollution" from sources other than erosion to make significant improvements in existing wet-weather quality of streams, lakes, etc.

____other (identify on back of sheet)

2. THE PRIORITY REASONS FOR PROVIDING SOLUTIONS FOR THE ABOVE NEEDS ARE: (rate by inserting numerals)

____to protect and enhance the market value of real property
____to safeguard human health and life
____to protect biota (flora and fauna)
____to maintain and improve aesthetics of water bodies and land areas
____to avoid possible fines and imprisonment associated with water-law violations
____to assure that local governments and agencies qualify for funding under various federal and state programs

____other (identify on back of sheet)

3. THE PRINCIPAL INSTITUTIONAL PROBLEMS DELAYING PROGRESS IN STORMWATER MANAGEMENT WITHIN OUR METROPOLITAN PLANNING AREA ARE: (rate by inserting numerals)

____lack of needed information and data base in our planning area (e.g.,--hydrology, native biota, ecology, present wet-weather water quality, etc.)

____lack of areawide policy, criteria, laws and guidelines for development of private and public stormwater management programs and facilities

____unmet financing needs
____legal problems that prevent or delay action
____apathy on part of public officials
____lack of citizen action and support
____inability to develop areawide approaches to stormwater management because of lack of authority to form multi-jurisdictional districts, authorities, etc.

____lack of cooperation between officials of the various local governments
____lack of qualified staff personnel in local governments and public agencies
____other (identify on back of sheet)

SUBMITTED BY:________________________ TITLE:______________ PHONE:______________ (Area, No.)

AGENCY:____________________________________ EPA REGION NO.__________

MAILING ADDRESS:____

____

(Form A)

GENERAL COMMENTS

Jerry G. Cleveland
Chief, Planning and Research
Tulsa City-County Health Department
Tulsa, Oklahoma

Most of you will be faced with the problem of trying to collect data and characterize stormwater in your local area. You will go through a sampling procedure on various watersheds. Doing it right is a big job. I recommend that you locate various types of small watersheds in your area and try to characterize those and apply some of the simplified models that are available. In this way, you can get a first-order of magnitude look at the problem. Maps of existing storm sewer systems are often not available. I found this to be true in Tulsa and other smaller cities in the metropolitan area.

The work that I did for the Office of Water Resources Research was done in the late 60's and early 70's, and the publications are out of print now. One of these presented simple models. Land use variables were included in the input data. I tried to verify these models by getting data from other cities and plugging it in with what I found at Tulsa. I had a reasonable degree of success in doing this in some areas; but, in other places, it didn't work at all. One must be very cautious in the application of various models obtained from various sources.

I have been trying to sell some kind of stormwater control activity to the policy-makers of the City of Tulsa. I made many presentations and have been very fortunate in having quite a bit of T-V coverage at various times, in Tulsa. It has been a hard sale; but, it looks like we are finally getting off the ground. We are trying to work this in conjunction with the more recent regulations coming out of my office--the Federal Flood Insurance Program and others. We are trying to develop regulations to comply with all of these federal programs, and the local governments are now starting to use stormwater detention techniques which Herb Poertner discussed. They are also using sedimentation control ordinances, landfilling ordinances and others. If you can get to the people who work in these fields--the City Engineer, Corps of Engineers, Soil Conservation Service, and others--you can jointly develop some regulations. If you integrate your work into the plans that they develop for stormwater control, you will make a lot of headways in controlling water pollution. They are trying to reduce flooding; but, at the same time, a simple change in design can accomplish a lot for pollution control. I am looking forward to doing this in Tulsa. We have a separate system for stormwater drainage. There are no combined sewers in Tulsa; however, we found many unusual results in sampling discharges from storm drains.

You should select the parameter that you need to control and see what impact its control will have on water quality. In some cases, you may wish to recommend to your state government, or the EPA, some changes in the water quality standards. In Tulsa, our biggest problem at this time appears to be solids. We hope that we have taken care of this with the sediment control ordinances. The solids, primarily, originate from developing areas and redevelopment projects. At certain times of the year, we also have problems with bacterial conditions on the Arkansas River which is classified for recreation. If we go by the current standards, we will have to chlorinate all our storm drainage. In a six-mile stretch of the Arkansas River below Keystone Dam, there are over 150 storm drains, not including creeks. So, the City of Tulsa may have 300 or 400 permits to issue.

QUESTIONS AND ANSWERS

(Following the third day of the Seminar in Atlanta)

__Question:__ Mr. Berteau, what are some of your experiences in efforts to get implementation of your planning?

__Berteau:__ First, we try to get citizen leaders, economic leaders and political decision makers involved in committee work. No major planning work element is undertaken until the Chairman of the Planning Commission obtains the approval of the involved counties. Subsequent to that, a prospectus is developed. Then, the committee goes to work with the staff and begins an inventory process, the development of alternatives and the synthesis of an ultimate plan. No implementation plan element is addressed without first having a strong implementation plan chapter in the prospectus. This chapter spells out what is expected of each local, State and Federal agency to bring about the implementation of the plan. A capital improvement schedule is also included in the prospectus.

__Question:__ Mr. Poertner, what do you think are the major problems that people have concerning urban stormwater?

__Poertner:__ Financing problems stand out above all others. In a few places, this doesn't seem to be a problem. For example, in Englewood, Colorado a 3% local sales tax is used to finance public improvements. One-third of this is allocated for stormwater management. The funds can be used for capital improvements as well as maintenance and operation. To illustrate the difficulty that is inherent in financing by formation of special assessment districts, between 1952 and 1968 not one drainage improvement district had been formed within the Denver Metropolitan Area. Other major problems are those that result from intergovernmental relationships between various local units of government in an urban, or suburban, area--particularly, in large metropolitan areas. The need to solve stormwater problems on a watershed basis, or regional basis, compounds the difficulty of providing solutions. For example, the financing problems are compounded.

Gast: The lack of widespread citizen awareness of stormwater problems and their consequences is a major problem. Also, many areas have not developed master plans for stormwater management. In some instances, local jurisdictions have had to forego funds that had been made available because of a lack of satisfactory plans.

Question: How do stormwater problems rank in importance in urban areas across the country in comparison with other water-related problems?

Poertner: Very high in most places in the country. There are exceptions, however. For example, in some semi-arid regions it is not considered a high priority problem. This also depends upon whether or not encroachment into the floodplains has been permitted to occur. In such cases, flooding may be a serious problem. Some areas of the country feel that stormwater pollution is not a significant problem.

Question: Mr. Dornbusch, what opportunities do you see for direct coordination between the 208 agencies and the local Soil Conservation Districts?

Dornbusch: I believe that Soil and Water Conservation Districtswill be involved in the implementation phase and in some of the activities of 208 agencies. From a technical standpoint, I believe that we will be a part of systems review.

Comment: In our technical and advisory committees, we have representatives of many agencies including: the District Engineer of the Chicago District Corps of Engineers, the Regional Administrator of Region V of the EPA, the Soil Conservation Service, the State Department of Natural Resources, and the Metropolitan Sewage Commissions. We have been successful in drawing upon all the disciplines that are involved. This is the way to solve the problems, because you can coalesce the efforts of all the agencies and persons involved.

Question (Goodwin, Illinois): What effort is being made at the Washington level to try to develop coordination among the various federal agencies, such as USDA, FHA, Economic Development Administration, and others, to assure that their programs, particularly the loan and grant program for the smaller communities, are going to be tied in to the 208 planning activity at the proper time and as a part of the total implementation program?

Waldo: I think that some of the intergovernmental problems will have to be solved at the local level. The interagency question that you posed is one that I do not wish to get into. But, I would like to stress that, whereas there may be uniform problems, there are not necessarily uniform solutions.

Question (Goodwin): Are you willing to admit that it is a problem and needs to be looked at?

Waldo: Yes.

Jensen: We testified before the Church Committee (Senator Church) on the act which establishes the Federal law for the U.S. Water Resources Council. Theoretically, the Council is supposed to provide leadership and coordination. Most of the states have been critical of the Council, thus far, and have made a variety of suggestions for its improvement. The Council itself, if properly constructed and operated, might be the best vehicle for coordination. The States have also suggested collectively, that they should have a council. The council should not be composed only of Federal agencies and should not be headed by a Federal department head, they feel.

Question (Goodwin): Mr. Jensen, you indicated that the State Water Control Board of Virginia expects local governments to solve their own problems. What do you do when the local governments fail to take action and there is no solution in sight?

Jensen: We are a regulatory agency. If communities don't want to find solutions, particularly for point-source problems, we have machinery to bring about coordination. We accomplish this state wide with no big problems in finding solutions. We get involved in court cases sometimes; however, we think it is better for the engineers to try to find solutions.

Appendix A

List of Seminar Participants
Atlanta, Georgia

NAME	AFFILIATION
Dennis Athayde	Wtr Plng Div., EPA/D.C.
Kathleen Adgate	" " " " "
Carl Myers	" " " " "
Richard Field	Storm Comb. Sewer Sect., EPA/NJ
Francis Condon	ORD, EPA/D.C.
Andrew Waldo	Wtr Plng Div., EPA/D.C.
Richard M. Cox	Central Mass Reg. Plng. Com.
Charles A. Knapp	Metcalf & Eddy, Inc
Lawrence J. MacMillan	EPA/Region I
J. Douglas Smith	Cambridge, Mass
Stephen C. Smith	Southeastern Reg. Plng. & Econ. Dev. Dist
Jose M. Cintron	Lebron, Santiorenco & Fuentes
William Pressman	Environ. Prot. Admin., NY City
Warren Kurtz	" " " " "
Charles Riesse	" " " " "
Paul S. Babiarz	Plng & Dev Board NY
Kevin Bricke	EPA/Region II
Bob Messina	" " "
Eugene A. Mattis	EPA/Region III
Charles App	" " "
Dennis Carney	" " "
Dale Wismer	" " "
David Longmaid	" " "
H.S. Edwards, Jr.	WVA Dept of Natural Resc.
Gary Burton	5th Plng Distric Comm., VA
James Hipps	Moore, Gradner, & Assoc., VA
Lester Slocum	Dept of Environ. Services, D.C.
Edward Halley	" " " " "
Ron Bartchy	Philadelphia Water Dept.
Dr. Richard C. Tortoriello	Dela. River Basin Comm., NJ
Andrew P. Pajak	Green Int'l Inc.
Joseph David, Jr.	" " "
Lawrence C. Phipps	SW VA 208 Planning Agency, VA
Paul E. Trammell	" " " " "
Ronald Flanary	" " " " "
Kenneth A. Bartal	Dept of Environ. Resources, PA
Henry Fabian Fostel	Regional Planning Council
Patrick E. Gallagher	Betz Environ. Engrs, Inc. PA
Whitey Secore	Metro Washington Council of Govts
Austin Librach	" " " " "
Roy Jeffrey	" " " " "
Joe Woodrick	" " " " "
Donald Van Sickle	Turner, Collie, Braden Consulting Engr.
Gordon Sparks	" " " " "

John Mickelson	" " " " "
William E. Toffey	Dela. Reg. Planning Commission
Luis Ajamil	Post, Buckley, Schuh & Jernigan
Ron Armstrong	Tampa Bay - St. Petersburg, FLA
Robert Barker	Waccamaw - Georgetown, S.C.
Michael Bell	" " "
Scott Berdine	EPA/Region IV
Barry Chefer	Polk County - FL
Greg Croxton	Columbia, S.C.
Ken Davis	Leon County - Tallahassee, FL
James Forbes	Greenville, S.C.
John Harvanek	EPA/Region IV
Al Herndon	EPA/Region IV
Ron Jernigan	Columbia, S.C.
Kenneth Jordon	Georgia - State
Robert J. Juster	Birmingham, AL
Lamar Larrimore	Tuscaloosa, AL
Alan Lumb	Columbia, S.C.
Robert Martin	Greenville, S.C.
Rick Martindale	Alabama - State
Tim McCartha	Alabama - State
Keith McCloud	Columbia, S.C.
Larry McCullough	Columbia, S.C.
Mike McAnelly	Columbia, S.C.
Jamal Nagamia	Polk County - FL
Nancy Parker	Georgia - State
Bill Patton	EPA/Region IV
Tom Pierce	Leon County - Tallahassee, FL
Dwaine Raynor	Pensacola, FL
David Reynolds	Triangle J - Raleigh-Durham
Frank Reynolds	Columbia, S.C.
Bob Rutter	Orlando - Winter Park, FL
Steve Sandler	EPA/REgion IV
Roland Santos	Dade County - Miami, FL
Stephen Sedgewick	Stanley Consultants
Robert Sherman	Georgia - State
John Shipp	Greenville, S.C.
Richard Stalker	Palm Beach County - FL
C.C. Taylor	" " " "
Joe Wanielista	EPA/Reion IV
Bill Whidden	Brevard County - FL
Russell Wright	EPA
David Word	Georgia - State
J.B. Jones	Columbia, S.C.
Richard J. Gregg	South & Central FL Flood Control Dist.
Michael Dunbar	Michigan Area Council of Govts
D. Galloway	SW Illinois Metro Reg. Plng Comm.
Dan Goodwin	EPA/Illinois
Jim Greener	EPA/Ohio
Mirza Meghji	Ohio-KY-Ind. Council of Govts

Kenneth Pew	Cleveland Reg. Sewer District
James Ruff	Wisc. Dept of Natural Resources
Paul Russell	SW ILL. Metro Reg. Plng Commission
Van Slyke	W. Mich. Shoreline Reg. Planning Comm.
G.K. Small	NE Ill. Planning Commission
J. Smedile	" " " "
P.J. Tyson	W. Mich. Shoreline Reg. Planning Commission

List of Seminar Participants
Denver, Colorado

NAME	TITLE	AFFILIATION
George Fink	Metcalf & Eddy	Consulting Engr.
A.S. Andrews	Sr. Water Resc. Engr.	Engineering Consultants, Inc.
Cecil Ouellette	Environ. Prot. Spec.	EPA/Oregon Oper. Ofc.
Gerald J. Gromko	Planning Engr.	Wastewater Mgmt. Div., Denver
John S. Griffith	Civil Engineer	Merrick & Co-Engrs., Denver
George Leavesley	Hydrologist	U.S.G.S., Denver
Emmett Haywood	Director, Plng. Div.	U.S. Dept. H.U.D.
Edwin H. Weber	Engineer	URS Company, Denver
Ben Urbonos	Water Resc. Engr.	Blatchley Assoc.
Gary Broetzman	208 Coordinator	Colo. Dept. of Health
Mike Miner	Project Coordinator	Weber River Plng. Co.
John Promise	Asst. Dir. of Water Resc.	North Central Texas COG
Dennis Maroney	Project Engr.	Karcich & Weber
John E. Fisher	Civil Engineer	Lawson Associates
H. Eugene Nielsen	Consulting Engr.	Nielsen, Maxwell & Wangsgard
Kenneth H. Bousfield	Civil Engineer	"" " " "
Robert Owen	Water Resc. Specialist	Colo. Water Cons. Board
Kathleen Adgate	Environ. Planner	EPA/Water Plng Div., D.C.
Dennis Athayde	Sanitary Engr.	EPA/Water Plng Div., D.C.
John Kingscott	Sanitary Engr.	EPA/D.C.
Keith Welch	Water Qual. Spec.	5 Co. AOG
C.H. Brewer	Program Mgr.	SEUA06
Michael D. Foreman	Sanitary Engr.	Iowa CIRALG
Charles W. Boyes	Staff Biologist	N. Central Texas COG
Ken Webb	Eng.	C.D.H.
Jon Scherschligt	Eng.	Colo. Dept. of Health
Daniel Straub	Project Planner	Rahenkamp, Sacks, Wells & Assoc.
John E. Galt	Section Head	Snohomish Cnty Plng Dept, Everett, WA
Donald G. Adams	Director, Water Resc.	Ark, Tex
George Hagevik	Asst Plng Director	ABAG, Berkeley, CA
Stephen Sowby	Mountainland Assoc.	Prov. UT
H. Lee Wimmer		
Erik Edeen	Eagle Co. Health Ofcr.	Eagle Co.
Duane Barter	Deputy State Cons.	USDA - SCS
Samuel J. Marcey	Wastewater Mgmt	Denver
Ken Watson	Water Quality Spec.	S.L.CO. 208 Study
Francis Condon	Sanitary Engr.	OR&D, U.S. EPA
Wayne S. Olsen	Sanitary Engr.	Corp of Engrs. - SF District
Ross Egbert	208 Coordinator	EPA/Region X
Hugh Meindl	Dire. Water Qual Prog.	South East Texas
Al Weing	208 Project Ofcr.	EPA/Region X
Jack Hibbert	Water Resc. Engr.	Denv. Reg. Co. of Govts.
Billy T. Black	Sanitary Engr.	EPA/Region VI

Mick Flynn	Head, Permits & Enforc. Div.	Guam Environ. Prot. Agency
George Clark	Water Division	EPA/Region IX
Herbert G. Poertner	Engr. & Research Consu.	Self-employed
Audrey E. Poertner	Research Assoc.	" "
Bill Taggart	Associate	Wright Mclaughlin Engr.
John Dumeyer	PE	Hydro Engineering, Pueblo
Richard Field	Chief, S&CS Section	EPA
Roland Crow	Asst. Director	
Michael Seaman	Senior Planner	Snohomish Co. (WA)
Bryon M. Parker	Admin. Flood Control	Salt Lake Co.
Andrew Waldo	Environ. Prot. Spec.	EPA/Water Plng. Div., D.C.
R. E. Thronson	Hydrologist	EPA/Washington, D.C.
William D. Evans	Areawide Plng Coord.	TWQB
Joe M. Bryan	Environ. Scientist	Houston-Galveston Area Counc.
Tommy D. Royal	Areawide Plng Coord.	Texas Water Qual. Board
George D. Holmes	Hydrologist	Corps of Engineers
Pedrito A. Francois	Environ. Engr.	V.I. Government
Bob Sallach	Engineer	H.D.R.
Rod Stroope	Mgr. Water Qual. Pln	Seattle, Metro
Hugh G. Hannah	Chief, Water Pol. Cont. Div.	Ark. Dept of Pol. Cont. Ecol.
Everett Perrien	Chief Planner	"" "" "" ""
Douglas B. Cargo	Asst Prof.	Univ. of Texas @ Dallas
Mike Kupko	Engineer	NHPQ
Alan Coburn	Environ. Engr.	URS Co. Seattle
Don A. Ostler	Engineer	Utah Bur. of Water Qual.
John Tarkong	Legal Counsel TEPB	Trust Terr. Env. Prot. Bd.
Art Kenke	Plng Mgr. Water Qual.	AACOG, San Antonio, TX
Nachsa Siren	Exec. Officer T.TEPB	Trust Terr. Env. Prot. Bd.
Leonard Crowe	208 Coordinator	Washoe Coun. of Govts., NV
Milton Sharp	Consultant	Sharp, Krater & Assoc. NV
Ronald Schuyler	Chief, Tech. Ser. Sect.	Colo. Dept of Health
William Ruzzo	Senior Engr.	Hydro Triad, LTD - CO
Richard D. Holland	Planner	Sante Fe, NM
William P. Fergus	Director	EDATA, Ohio
Gordon McLean	Planner	EDATA, Ohio
Larry Fassett	Environ. Engr.	South Eastern
Ronald K. Blatchley	Wtr. Resc. Engr.	Blatchley Assoc.
Paul Ferraco	208 Coordinator	EPA/Region VIII
C.O. Bakken	Specialist	City & Cnty of Denver
James Williams	Engineer	Nevada Envir. Prot. Serv.
Thomas E. Neal	208 Project Coord.	Mid-America Regional Coun.
Peter L. Smith	Project Director	Ozark Gateway RPC Missouri
Larry Sheridan	Sanitary Engr.	EPA/Region VII
Ron Peterson	Planning Engr.	OK Dept Pollution Control
Lee Duvall	Engineer	EPA/Region VII
Jerry G. Cleveland	Chief, Plng & Research	Tulsa City Cnty Health Dept
Robert L. Braun	Environ. Engr. Spec.	Idaho Dept of Health & Wel.
R. W. Fritz	Regional Engr.	ACOG
Donald Hay	Vice President	Hydro
Deborah Pile	Planner	MN Poll. Control Agency

Tom Pitts	Manager	Toups Corporation
John	Environ. Planner	EPA/Region VIII
Max H. Dodson	208 P.O.	EPA/Region VIII
John A. Lager	VP	Metcalf & Eddy
E.D. Driscoll		Hydroscience
Sam	Sanitary Engr.	EPA/Region VI
Bill Honker	Sanitary Engr.	EPA/Region VI
Skip McKay	Planning	Assoc. of Bay Area
LaVere B. Merritt	208 Project Director	
D.S. Pate	Sen. Water Plng. Spec.	CO Water Cons. Bd
Foe Foreman	208 Tech. Planner	Pueblo Reg. Plng Com
Herb McCall	Principal	McCall
Ed Wesolowski	208 Proj. Dir.	Lewis & Clark, ND
Dale	Chief Control Tech Sec.	EPA/Region VIII
Bob Shankland	Sanitary Engineer	EPA/Region VIII
Bob Mairley	Biologist	EPA/Region VIII
Ken Young	Principal	GKY & Assoc. VA
R.F. Goddard	Planner	Terma, Inc.
Daniel Law	Water Resc. Engr.	Denver Regional COG

Appendix B

URBAN STORMWATER MANAGEMENT SEMINAR

sponsored by

U. S. Environmental Protection Agency

Water Planning Division

Washington, D.C.

November 4,5 and 6, 1975

Sheraton - Biltmore
Atlanta, Georgia

TUESDAY

NOVEMBER 4, 1975

CHARACTERIZATION OF THE URBAN STORMWATER PROBLEM

Moderator: Dennis Athayde, Water Planning Division, EPA

AM

8:15 Registration

9:00 Welcoming Remarks: John A. Little, Deputy Regional Administrator, Region IV, EPA

9:10 Introduction to Program: James Meek, Water Planning Division, EPA, Washington, D.C.

9:15 Best Management Practices (BMP): Dennis Athayde, Water Planning Division, EPA, Washington, D.C.

9:35 Characterization of Urban Stormwater Problems: Frank Condon, Office of Research and Development, EPA, Washington, D.C.

10:05 Break

10:25 Urban Development and Land Use Affecting Water Quality: Herbert Poertner, Engineering & Research Consultant

11:00 Instream Impacts of Urban Runoff: Eugene Driscoll, Hydroscience

11:30 Impact of Combined Sewer Overflows/Storm Sewer Discharges on Water Quality: John Lager,Metcalf & Eddy, Inc.

PM

12:00 Lunch

1:15 Measuring Runoff and Sampling Techniques: Eugene Driscoll, Hydroscience

2:30 Modelling: John Lager, Metcalf & Eddy, Inc.

3:30 Break

3:50 Q/A Period (Tuesday Speakers)

4 ;30 Adjournment

WEDNESDAY

NOVEMBER 4, 1975

APPROACHES TO URBAN STORMWATER PROBLEMS

Moderators: Richard Field and Kathleen Adgate, EPA

AM

9:00 Stormwater Film

9:35 Collection System Control: John Lager, Metcalf & Eddy, Inc.

10:05 Break

10:25 Combined Sewer Approach: William Pisano, Energy & Environmental Analysis, Inc.

11:25 Housekeeping Techniques and Construction Practices: Land Management Controls for Developed and Developing Areas: Kathleen Adgate, Water Planning Div., EPA

PM

12:00 Lunch

1:15 Detention/Flow Attenuation: Herbert Poertner, Engineering and Research Consultant

1:45 Swirl Concentrators: Richard Field, Storm and Combined Sewer Section, EPA, Edison, N.J.

2:05 NPS Impact and Urban Holding Capacity: Major Issues - G. Kenneth Young, GKY & Associates

2:40 Break

3:00 Q/A Period (Wednesday Speakers)

4:00 Adjournment

THURSDAY

NOVEMBER 6, 1975

INSTITUTIONAL AND LEGAL ISSUES

Moderator: Herbert Poertner, Engineering & Research Consultant

AM

9:00 Nationwide Study of Problems/Solutions to Urban Stormwater Management: Herbert Poertner, Engineering & Research Consultant

9:30 The Intergovernmental Tangle Facing Stormwater Control: Andrew Waldo, Water Planning Division, EPA, Washington, D.C.

10:10 State - Local Coordination in Virginia: Eugene Jensen, Executive Secretary, Virginia State Water Control Board

10:40 Break

10:50 Financing Stormwater Projects: James R. Fountain, Jr., Director of Finance, Fulton County, Georgia

11:40 Lunch

PM

1:00 SCS, 208 Relationships: A. J. Dornbusch, Jr., State Conservation Engineer, SCS

1:20 Legal Aspects: Frank E. Maloney, Professor of Law, University of Florida

2:00 Planning to Narrow the Implementation Gap: George Berteau, Chairman, Southeastern Wisconsin Regional Planning Commission

2:45 Break

3:00 Q/A Period (Thursday Speakers)
Moderator: Warren Gast

4:00 Adjournment

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

URBAN STORMWATER MANAGEMENT SEMINAR

sponsored by

U. S. Environmental Protection Agency

Water Planning Division

Washington, D.C.

December 2, 3 and 4, 1975

Cosmopolitan Hotel
Denver, Colorado

TUESDAY

December 2, 1975

Characterization of the Urban Stormwater Problem

Moderator: Dennis Athayde, Water Planning Division, EPA.

AM

8:15 Registration

8:55 Announcements

9:00 Welcoming Remarks: Charles Murray, Division Director of Water Programs, EPA, Region VIII

9:10 Introduction to Program: Dennis Athayde, Water Planning Division, EPA, Washington, D.C.

9:35 Instream Impacts of Urban Runoff: Eugene Driscoll, Hydroscience

10:15 Break

10:30 Characterization of Urban Stormwater Problems: Frank Condon, Office of Research and Development, EPA, Washington, D.C.

11:10 Impact of Combined Sewer Overflows/Storm Sewer Discharges on Water Quality: John Lager, Metcalf & Eddy, Inc.

11:50 Lunch

PM

1:15 NPS Impact and Urban Holding Capacity: Major Issues - G. Kenneth Young, GKY & Associates

1:55 Measuring Runoff and Sampling Techniques: Eugene Driscoll, Hydroscience

3:15 Break

3:30 Applications of Stormwater Management Models: John Lager, Metcalf & Eddy, Inc.

4:10 Adjournment

4:15 Regional Sessions

5:30 Cash Bar

WEDNESDAY

December 3, 1975

Approaches To Urban Stormwater Problems

Moderator: Kathleen Adgate, Water Planning Division, EPA

AM

9:00 Introduction to Program: Dennis Athayde, Water Planning Division EPA, Washington, D.C.

9:15 Housekeeping Techniques: Land Management Controls for Developed Areas - Kathleen Adgate, Water Planning Division, EPA, Washington, D.C.

9:40 Construction Practices: Land Management Controls for Developi Areas - Duane Bartee, Deputy State Conservationist, Soil Conservation Service, Denver

10:20 Break

10:40 Collection System Control · John Lager, Metcalf & Eddy, Inc.

11:20 - Cost-Effective Approach For Combined and Storm Sewer Cleanup: William Pisano, Energy and Environmental Analysis, Inc.

11:50 Lunch

PM

1:00 Stormwater Film

1:40 Swirl Concentrators: Richard Field, Storm and Combined Sewer Section, EPA, Edison, N. Jersey

2:20 Detention/Flow Attenuation: Herbert Poertner, Engineering and Research Consultant

2:45 Break

3:00 Discussion Groups

4:30 Adjournment

THURSDAY

December 4, 1975

Institutional and Legal Issues

Moderator: Andrew Waldo, Water Planning Division, EPA

AM

9:00 Introduction to Program: Dennis Athayde, Water Planning Division, EPA, Washington, D.C.

9:10 The Intergovernmental Tangle Facing Stormwater Control: Andrew Waldo, Water Planning Division, EPA, Washington, D.C.

9:40 Legal Aspects of Urban Stormwater Management: Senator Joseph Shoemaker, Denver, Colorado

10:20 Break

10:40 Financing Stormwater Projects: Senator Joseph Shoemaker, Denver, Colorado

11:10 Planning To Narrow The Implementation Gap: Richard Page, Seattle Metro

11:50 Concluding Remarks: Dennis Athayde

12:00 Adjournment

*U.S. GOVERNMENT PRINTING OFFICE: 1976 625-723/773 1-3